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ÉVALUATION DES FACTEURS DE RISQUE DE TROUBLES MUSCULO-SQUELETTIQUES : COMPARAISON DE MÉTHODES D'OBSERVATION ET PERCEPTION DES TRAVAILLEURS

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ÉVALUATION DES FACTEURS DE RISQUE DE TROUBLES MUSCULO-SQUELETTIQUES : COMPARAISON DE MÉTHODES D'OBSERVATION ET PERCEPTION DES TRAVAILLEURS

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RÉSUMÉ

Les troubles musculo-squelettiques constituent un problème de taille dans la majorité des pays industrialisés. Selon les chiffres de *l'Enquête sur les conditions de travail, d'emploi et de santé et de sécurité du travail*, récemment publiée, un québécois sur cinq (20,5%) souffrirait de troubles musculo-squelettiques (TMS) liés au travail. Les TMS comptent pour 38% des lésions indemnisées par la Commission de la Santé et de la sécurité du travail. L'intervention ergonomique visant la réduction de l'exposition aux facteurs de risque de TMS demeure la meilleure stratégie de prévention et cette intervention est subordonnée à l'identification de ces facteurs de risque. La littérature récente en ergonomie propose une variété de méthodes d'observations ayant été développées afin d'estimer l'exposition aux facteurs de risque de TMS. Elles ont pour objectif de supporter la prise en charge de la prévention des TMS en entreprise. Toutefois, cette littérature offre encore peu de recherches appliquées mettant à l'épreuve ces méthodes sur le terrain pour comparer les résultats qu'elles produisent.

Cette thèse réalise une analyse comparative des résultats obtenus à partir de 11 méthodes d'évaluation des facteurs de risque de TMS basées sur l'observation et étudie le lien entre la déclaration de la douleur et la perception des travailleurs quant à l'évaluation de leur poste de travail. Les résultats de 21 indices tirés des 11 méthodes ont été comparés par groupes homogènes. Au total, 224 postes de travail ont été évalués, dans 18 entreprises provenant de secteurs d'activité économique variés. Les données ont été recueillies à partir de vidéos et de mesures prises aux postes. Un questionnaire fut également administré aux sujets ayant participé à l'étude, comportant des questions sur leurs caractéristiques

personnelles générales, leur perception des facteurs de risque liés à l'ergonomie ainsi que sur les douleurs ressenties au cours des 12 derniers mois et des sept derniers jours précédant la collecte de données.

La première étude de la thèse présente une analyse comparative des résultats de six méthodes permettant d'évaluer les facteurs de risque de TMS au dos (QEC, *Ergonomic Workplace Analysis* du FIOH : Finnish Institute of Occupational Health, 3D SSPP, 4D WATBAK, A Guide to Manual Material Handling de Mital et al. 1997 ainsi que la norme EN 1005-3). La deuxième étude se penche sur deux groupes de méthodes. Dans un premier groupe, les résultats que produisent les méthodes permettant d'évaluer les facteurs de risque de façon plus globale ou pour plus d'une zone corporelle sont comparés (QEC, *Ergonomic Workplace Analysis* du FIOH, RULA et REBA). Le deuxième groupe, se penche sur les méthodes permettant d'évaluer les facteurs de risque de TMS aux membres supérieurs (ACGIH HAL, Job Strain Index, OCRA, QEC et la norme EN 1005-3). Les deux études permettent d'évaluer les niveaux de risque obtenus à partir des différentes méthodes. Les résultats sont comparés selon trois catégories de risque (faible, modéré, élevé) et révèlent d'importantes différences entre les méthodes quant à la détermination du niveau de risque. Parmi les paires de méthodes comparées, près de la moitié d'entre elles évaluant le risque au dos montraient des écarts de deux niveaux de risque pour un poste sur cinq. La comparaison des méthodes par groupe homogène révèle des écarts parfois significatifs entre les méthodes d'un même groupe. Aucune paire de méthodes ne semble en accord parfait. Les résultats présentés dans les deux premières études permettent de constater qu'un poste de travail peut être considéré à risque par une méthode et ne pas l'être par une autre. Les résultats illustrent les conséquences potentiellement importantes du choix d'une méthode sur la détermination des priorités dans le cadre d'une intervention d'identification des postes les plus à risque dans une entreprise. L'analyse des méthodes en fonction de l'identification de leurs priorités (i.e., postes considérés comme étant les plus à risque par une méthode) a permis de montrer que certaines d'entre elles demandant moins d'effort peuvent produire des résultats semblables quant à l'identification des postes à risque. Les résultats montrent aussi que certaines méthodes pourraient être privilégiées par rapport à d'autres si une approche plus conservatrice était recherchée.

La troisième étude compare l'évaluation des facteurs de risque liés à l'ergonomie par des travailleurs avec et sans douleurs musculo-squelettiques. La méthode *Ergonomic Workplace Analysis* du FIOH a été utilisée par les travailleurs et par un expert en ergonomie pour l'évaluation des postes de travail. Également, la qualité ergonomique du poste de travail et la nécessité d'y apporter des changements ont été évaluées sur une échelle visuelle analogue par l'expert et par les travailleurs du poste. Les résultats révèlent que les sujets ayant déclaré des douleurs au cours des sept derniers jours évaluent leur poste de travail plus négativement que les sujets ne déclarant pas de douleur et ce, même si l'expert ne voit pas de différence entre les postes de travail des deux groupes. Cette dernière étude permet de constater que l'évaluation d'un expert est probablement préférable lorsqu'il s'agit d'identifier les postes à risque. Les résultats de notre étude démontrent que l'opinion du travailleur est moins fiable, puisqu'elle varie selon la présence de douleur ou non.

Toutefois, même si cette information est "subjective", l’opinion du travailleur permet de recueillir de l’information qui est, autrement, difficile à obtenir avec une méthode se basant uniquement sur l’observation du travail. Ces résultats pourront permettre au praticien d'avoir une bien meilleure idée de ce à quoi il doit s’attendre lorsqu’il fait le choix d’utiliser une méthode plutôt qu’une autre pour effectuer l’évaluation d’un poste de travail. Considérant ces résultats, la recherche devrait se poursuivre pour développer un outil d’aide à la décision quant choix d’une méthode d’évaluation des facteurs de risque de TMS.

ABSTRACT

The prevalence of musculoskeletal disorders (MSDs) in workplaces is a major problem. According to the recently published *Enquête sur les conditions de travail*, d'emploi et de *santé et de sécurité du travail*, one in five Quebeckers (20,5%) suffer from MSDs. MSDs represent 38% of all injuries compensated by Quebec's worker compensation board. Given the significant impacts of MSDs, industries need to work on prevention. The scientific literature shows that intervention to reduce exposure to MSD risk factors is the best prevention strategy. Recent literature in ergonomics offers a variety of observation methods for MSDs risk factors assessment. Some were developed with the intention of supporting industry-led MSDs prevention efforts and provide important guidelines for the implementation of occupational health and safety strategies. Yet, the existing literature showcases little applied research that tests these methods in the field to compare the results they produce.

This doctoral thesis performs a comparative analysis of results obtained from 11 methods of MSDs risk factors assessment based on observation, and studies the relationship between the declaration of pain and perceptions of workers regarding the assessment of their workstations. The results of 21 indices from the 11 observation-based methods are compared in homogeneous groups. In total, 224 workstations were evaluated, involving 567 different tasks in 18 firms from various sectors of the economy. Data were gathered using video and measurements taken at the workstations.

A questionnaire on the musculoskeletal pain experienced in various body regions, during the 12 months and seven days prior to the data collection, was also administered to employees participating in the study.

The first article of this doctoral thesis compares the results obtained from methods most likely to be used by practitioners when assessing risk factors for MSDs of the back. Six methods are analyzed: the QEC (Quick Exposure Check), the *Ergonomic Workplace Analysis* of the FIOH (Finnish Institute of Occupational Health), 3D SSPP, 4D WATBAK, *A Guide to Manual Materials Handling* by Mital et al. (1997) and the EN 1005-3 standard. The second article focuses on two groups of methods. In a first group, the methods assessing upper limbs risk factors are compared with each other (ACGIH HAL, Job Stain Index, OCRA, QEC, and the EN 1005-3 standard). In a second group, more general MSDs risk assessment methods are compared (FIOH's *Ergonomic Workplace Analysis*, QEC, RULA, and REBA). The results are compared using three risk categories (low, moderate, high).

Results reveal significant differences between methods in determining the level of risk. Among the methods compared in pairs, almost half evaluating the risk on the back showed differences of two risk level categories for one workstation out of five. Comparison of the methods from homogeneous groups reveals discrepancies between the methods that are sometimes significant within the same group. No pair of methods seems in perfect agreement. The results presented in the studies show that a workstation may be considered at risk by one method and not by another. These results illustrate the potentially important consequences of choosing a method for determining priorities in the context of a screening intervention in a company. The analysis of methods based on the identification of priorities (i.e. workstations that are considered most at risk by a method) has shown that some methods requiring less effort can produce similar results regarding the identification of the workstations that are at risk. Results also show that some methods should be preferred to others if a more conservative approach is sought.

The third study compares the evaluation of risk factors related to ergonomics for workers with and without musculoskeletal pain. FIOH's *Ergonomic Workplace Analysis* was used by workers and by an expert for the evaluation of the workstations. Also, the ergonomic quality of the workstation and the need to make changes were graded on a visual analogue scale (VAS). The results show that those who reported pain in the seven days prior to the assessment evaluated their workstations more negatively than subjects who reported no pain, while the expert found no difference between the workstations of the two groups.

The results of our study show that the opinion of the worker is less reliable since it depends on the presence of pain or not. However, even if this information is a 'subjective' opinion of the worker, it supplies information that is otherwise difficult to obtain with a method based solely on observation. The results of this research help practitioners to have a much better idea of what to expect when they choose one method over another to perform the evaluation of a workstation. Considering these results, research should continue to develop decision making aids for choosing a method to evaluate MSDs risk factors.

TABLE DES MATIÈRES

LISTE DES TABLEAUX

LISTE DES FIGURES

LISTE DES ABRÉVIATIONS

AL : Action limit

BCDL : Back compression design limit

BCUL : Back compression upper limit

CPE: Certified Professional Ergonomist

CSST : Commission de la santé et de la sécurité du travail du Québec

EQCOTESST : Enquête québécoise sur des conditions de travail, d'emploi et de santé et de sécurité du travail

EN 1005-3 : Norme EN 1005 Partie 3 : limites de forces recommandées pour l'utilisation de machines

ESS98 : Enquête sociale et de santé 1998

FIOH : Finnish Institute of Occupational Health

HAL : American Conference of Gouvernmental Industrial Hygienists Hand Activity Level

IRSST : Institut de recherche Robert-Sauvé en santé et en sécurité du travail

ISQ : Institut de la statistique du Québec

JSI : Job Stain Index

LBP index : Low back Pain index

MAWL : Maximum acceptable weight of lift

MPL: Maximum Permissible Limit

MSD : Musculoskeletal disorders

ND : données non disponibles

NIOSH : National Institute for Occupational Safety and Health

NRC/IM: National Research Council-Institute of Medicine

NSERC : National Sciences and Engineering Research Council of Canada

OCRA : Occupational Repetitive Action method

OMS: Organisation mondiale de la santé

QEC : Quick Exposure Check

REBA : Rapid Entire Body Assessment

Rsld : Resulting moment/25th percentile maximum moment

Rsul : Resulting moment/99th percentile maximum moment

RULA : Rapid Upper Limb Assessment

SDL: Strength Design Limit

SUL: Strength Upper Limit

TMS : Troubles musculo-squelettiques

VAS : Visual Analogue Scale

4D WATBAK : 4D WATBAK biomechanical modeling method

3D SSPP : Three-Dimensional Static Strength Prediction Program

CHAPITRE 1: INTRODUCTION

1.1 Problématique

Selon les chiffres de l'Enquête sur les conditions de travail, d'emploi, et de santé et de sécurité du travail (EQCOTESST 2011), récemment publiée, un québécois sur cinq (20,5%) souffrirait de troubles musculo-squelettiques (TMS) liés au travail. Les TMS comptent pour 38% des lésions indemnisées par la Commission de la santé et de la sécurité du travail (CSST), représentant une facture annuelle de plusieurs centaines de millions de dollars. Le constat n'est pas différent dans les autres pays industrialisés (Buckle et Devereaux 2002 ; OMS 2003 ; Yelin 2003).

Les conséquences économiques et sociales des TMS sont importantes (Morse et al. 1998 ; Punnett et Wegman 2004). Selon une étude de Santé Canada (2002), les TMS se placent au deuxième rang des pathologies les plus coûteuses, derrière les maladies d'origine cardiovasculaire et celles associées à un cancer. Les absences du travail, les pertes de productivité et les impacts sur la qualité des produits représentent des coûts importants pour les entreprises. En 2007, 114 000 salariés québécois rapportaient s'être absentés du travail en raison de douleurs musculo-squelettiques entièrement reliées au travail (EQCOTESST 2011). Pour les travailleurs atteints de TMS ou qui en ressentent les symptômes, les effets dans leur vie personnelle et leurs activités sont aussi considérables.

À l'ère de la réorganisation du travail dans l'objectif d'améliorer les performances de l'entreprise, les répercussions sur la main-d'œuvre sont à craindre. Cette situation pose un défi important pour les travailleurs et les employeurs puisqu'il est peu probable qu'elle s'améliore à moins de déployer des efforts sérieux en prévention.

Plusieurs études épidémiologiques tracent un lien évident entre la charge de travail physique et le risque de développer des TMS (Grieco et al. 1998 ; Hoogendoorn et al. 2000 ; Marras et al. 1995 ; NIOSH, 1997 ; NRC/IM 2001 ; Punnett et Wegman 2004 ; Stock 1991). Le National Institute for Occupational Safety and Health (NIOSH 1997) et le National Research Council (NRC/IM 2001) rapportent un lien significatif entre le développement de TMS et certains facteurs de risque : charges manutentionnées, application de forces excessives, postures contraignantes, vibrations, répétitions, etc. La littérature fournit aussi des évidences quant à la contribution des facteurs psychosociaux dans le développement d'une lésion musculo-squelettique (Westgaard et al. 1993).

L'intervention ergonomique visant la réduction de l'exposition aux facteurs de risque de TMS demeure la meilleure stratégie de prévention (Burdorf 2010 ; NRC/IM 2001, Silverstein et Clark 2004). L'intervention passe donc par l'identification de ces facteurs de risque. Sans la connaissance de ce qui cause l'apparition de douleurs ou le développement d'une lésion, il est difficile d'agir pour modifier la situation de travail.

1.2 Origine de la recherche

1.2.1 Méthodes d'évaluation des facteurs de risque de TMS

Les méthodes d'évaluation de l'exposition aux facteurs de risque de TMS peuvent être classifiées en trois catégories selon Burdorf et van der Beek (1999) : jugement subjectif (ex. questionnaire et échelle de mesure), observations systématiques et mesures directes.

Bien que les méthodes de mesures directes ressortent dans la littérature comme les plus précises et les plus fiables (Juul-Kristensen 2001), elles exigent en contrepartie un investissement important en termes de ressources. De plus, en l'absence de valeurs seuils, plusieurs des mesures qu'elles produisent demeurent difficiles à interpréter en termes de risque pour les personnes exposées. Les méthodes d’observation, plus facile à mettre en œuvre, restent les méthodes les plus utilisées par les praticiens (Genaidy et al. 1994 ; Takala et al. 2010).

La littérature récente en ergonomie propose une variété de méthodes d’observation développées pour des praticiens, bien que certaines d’entre elles soient aussi utilisées par des chercheurs (David 2005 ; Imbeau et Fradet 2004 ; Li et Buckle 1999a ; Malchaire et al. 2001). Certaines méthodes se différencient par leur caractère plus général ou le fait qu’elle ciblent plusieurs zones corporelles (ex. Buchholz et al. 1996 ; David 2003 ; Hignett et McAtamney 2000 ; Karhu et al. 1977) alors que d’autres ciblent les facteurs de risque pour une zone corporelle en particulier comme le dos (ex. Mital et al. 1997 ; Snook et Ciriello 1991 ; Waters et al. 1994) ou les membres supérieurs (ex. Colombini 1998 et Occhipinti 1998 ; McAtamney et Corlett 1993 ; Moore et Garg 1995).

Ces méthodes permettent d’intervenir efficacement en priorisant les interventions. En d’autres termes, elles permettent d’identifier les postes les plus critiques. Non seulement ces méthodes peuvent-elles aider à décider où déployer des efforts de prévention, mais elles peuvent aussi permettre de faire une surveillance des facteurs de risque de TMS aux postes de travail. Utilisées par des chercheurs aussi bien que par des non-chercheurs, les méthodes d’observation sont plus faciles d’utilisation, exigent des moyens simples (ex., papier crayon, photo) et plus flexibles pour la collecte de données sur le terrain.

Malgré le fait qu’il existe plusieurs méthodes publiées, peu d’informations sont disponibles sur les résultats qu’elles produisent. Ces connaissances sont importantes pour le chercheur comme pour le praticien. Les auteurs de ces méthodes font typiquement état d'une forme de validation relativement limitée et rarement documentée, tout en exprimant le désir que leur méthode soit validée sur une plus vaste échelle (McAtamney et Corlett 1993 ; Hignett et McAtamney 2000 ; Seth et al. 1999). En ce qui a trait aux normes et projets de normes internationales (ex. EN) ceux-ci apparaissent encore trop récents pour avoir fait l'objet d'une comparaison avec d'autres méthodes moins récentes voire d'une validation.

Quelques études dressent un portrait des méthodes qui nous sont offertes dans la littérature en nous présentant leurs différentes caractéristiques : type de méthode, facteurs de risque pris en compte, validité et fiabilité (David 2005 ; Li et Buckle 1999a ; Kilbom 1994 ; Malchaire et al. 2001 ; Takala et al. 2010). Peu d'études présentent des analyses quantitatives comparant ces méthodes afin de déterminer si elles produisent des résultats similaires. Un certain nombre d'études[1] présentent certes des résultats comparant entre deux et cinq méthodes d'évaluation des facteurs de risque de TMS. À l'exception de l'étude de Kee et Karwowski (2007) comparant les méthodes REBA et RULA avec des données qui proviennent d'un échantillon de 301 postures recueillies dans des secteurs variés, et celle de Spielholz et al. (2008) comptant 567 participants provenant de deux secteurs (manufacturier et hospitalier) et comparant le Job Strain Index et le ACGIH Hand Activity Level, les comparaisons portent généralement sur des échantillons de petite taille et/ou provenant d'un unique milieu de travail.

[1] Apostoli et al. (2004) ; Bao et al. (2006) ; Brown et Li (2003) ; Burdorf et Laan (1991), Drinkaus et al. (2003) ; Jones et Kumar (2007) ; Jones et Kumar (2010) ; Joseph et al. (2011), Kee et Karwowski (2007), Lavender et al. (1999), Marklin et Wilzbacher (1999), Marras et al. (1999), Russell et al. (2007), Sala et al. (2010) ; Spielholz et al. 2008 ; van der Beek et al. (2005) et Waters et al. (1998).

En nous basant sur une méta-analyse de la littérature réalisée par Imbeau et Fradet (2004), 21 méthodes d'évaluation des facteurs de risque de TMS basées sur l'observation ont été identifiées. Les auteurs ont pu constater que chaque méthode combine différents facteurs de risque d'une façon qui lui est propre et fait aussi l'usage d'une échelle d'évaluation du risque unique. Un autre constat important de ces auteurs est que peu de méthodes ont fait l'objet d'une forme de validation et d'une évaluation de leur fiabilité à grande échelle. Ces méthodes varient aussi énormément en termes de facilité d'utilisation et le niveau d'expertise requis pour les mettre en application peut être très variable. Le temps nécessaire pour la réalisation d'une évaluation des facteurs de risque de TMS à un poste de travail est aussi une des caractéristiques qui les différencie les unes des autres. L'intégration de l'opinion du travailleur dans la détermination du niveau de risque caractérise aussi quelques méthodes. Nombre de méthodes permettent d'obtenir un niveau de risque, mais aussi un pointage qui peut permettre de comparer une situation avant vs après transformations à un poste de travail. D'autres sont plus analytiques et permettent d'obtenir une valeur seuil qui peut guider l'utilisateur lors de la réalisation d'interventions visant la mise en place de transformations sans toutefois représenter le meilleur choix pour une étape de dépistage des postes les plus à risque parmi un large échantillon de postes.

Le fait que les méthodes d'observation des facteurs de risque de TMS se distinguent toutes les unes des autres rend difficile le choix d'une méthode pour les praticiens, les entreprises et les organismes responsables de la prévention des TMS. Une première étape afin de nous éclairer sur le choix d'une méthode plutôt qu'une autre consiste à comparer leurs résultats en les testant sur le terrain (Denis et al. 2005).

1.2.2 Perception des travailleurs et évaluation des facteurs de risque ergonomiques

Les interventions en ergonomie visant la réduction de l'exposition aux facteurs de risque de TMS à un poste de travail devraient se faire avec la collaboration des travailleurs. L'approfondissement des connaissances concernant l'activité de travail requiert également la participation des travailleurs. Dans cet esprit, certaines des méthodes d'évaluation des facteurs de risque ont été développées en combinant l'évaluation du travailleur et de l'expert dans la détermination du niveau de risque à un poste de travail. C'est le cas des méthodes QEC (Li et Buckle 1999b, 1999c ; David et al. 2003, 2008) et *Ergonomic Workplace Analysis* du FIOH (Ahonen et al. 1989), décrites plus en détails aux chapitres 3, 4 et 5.

Étant donné l'importance de la prévalence des TMS dans la population, il est normal de croire que ces méthodes peuvent être utilisées pour évaluer des postes de travail où les travailleurs ressentent des symptômes de TMS. Il devient donc pertinent de savoir si la perception des travailleurs peut être affectée par le fait qu'ils ressentent de la douleur lorsque de telles méthodes sont utilisées.

Jusqu'à présent, seulement quelques études se sont intéressées à ce sujet. Certains chercheurs ont observé que les travailleurs atteints de TMS ou souffrant de douleurs rapportent une exposition plus élevée aux facteurs de risque de TMS (Balogh et al. 2004 ; Hansson et al. 2001 ; Leijon et al. 2002 ; Viikari-Juntra et al. 1996). Ces études comparent les différences dans l'évaluation de l'exposition chez un groupe de travailleurs souffrant de douleurs et un groupe sans douleur pour différentes variables telles que les tâches de manutention manuelle, les mouvements répétitifs et les postures de certaines régions du corps. Donders et al. (2007) ont démontré par leurs résultats que les travailleurs souffrant de maladies ou douleurs chroniques répondaient plus négativement à des questions reliées aux caractéristiques de leur travail que les travailleurs ne souffrant pas de maladie ou de douleur chronique. Leur étude établit que cette perception négative du travail était fortement reliée à la douleur chronique plutôt qu'à de réelles mauvaises conditions de travail, car tous les sujets de l'étude travaillaient pour la même entreprise et sur des postes de travail semblables. Parmi les études publiées à ce jour, les expositions aux facteurs de risque de TMS étudiées sont relativement semblables. Également, aucune de ces études n'a utilisé l'une des méthodes d'observation développée à l'intention des praticiens en ergonomie. En fait, on ne sait pas si ces méthodes, lorsqu'utilisées dans un contexte de pratique en ergonomie, sont sujettes à produire les mêmes effets que ceux observés lorsque des méthodes spécifiquement développées par des chercheurs pour leur contexte précis de recherche sont utilisées.

CHAPITRE 2 : PRÉSENTATION DE LA THÈSE, DES TERRAINS DE RECHERCHE ET DE LA COLLECTE DE DONNÉES

2.1 Présentation de la thèse

À partir d'une vaste collecte de données effectuée en entreprise, cette thèse s'intéresse à l'évaluation des facteurs de risque de TMS à un poste de travail. Elle compare les résultats obtenus à l'aide de 11 méthodes d'observation différentes et étudie le lien entre la déclaration de la douleur et la perception des travailleurs quant à l'évaluation de leur poste de travail.

Les deux premières études présentent une analyse comparative des 11 méthodes par groupe homogène (figure 1). Les méthodes d'évaluation des facteurs de risque de TMS, décrites plus en détail aux chapitres 3 et 4 de la thèse et retenues dans le cadre de cette étude sont :

- Quick Exposure Check (QEC) (Li et Buckle 1999b, 1999c ; David 2003, 2008) ;
- *Ergonomic Workplace Analysis* du FIOH (Ahonen, Launis et Kuorinka 1989) ;
- Rapid Upper Limb Assessment (RULA) (McAtamney et Corlett 1993) ;
- Rapid Entire Body Assessment (REBA) (Hignett et McAtamney 2000) ;
- ACGIH Hand Activity Level (HAL) (American Conference of Governmental Industrial Hygienists 2002) ;
- Job Strain Index (JSI) (Moore et Garg 1995) ;
- OCRA (Colombini 1998 ; Occhipinti 1998) ;
- 3D Static Strength Prediction Program (3DSSPP, V5.0 et V6.0) (Université du Michigan 2001) ;
- 4D WATBAK (Université de Waterloo 1998) ;
- *A guide to Manual Materials Handling* (Mital et al. 1997) ;
- La norme EN 1005-3 (EN 2002).

Le choix des méthodes s'est fait dans une perspective de facilité d'utilisation et d'accessibilité. Elles représentent un échantillon de méthodes de complexité variable, ciblent des zones corporelles différentes ou proposent une évaluation plus globale. Finalement, elles sont susceptibles d'être utilisées par des non-chercheurs d'expertise variable en ergonomie. D'ailleurs, la méthode QEC a déjà été adoptée par la CSST dans le cadre de son plan d'intervention sur les TMS. Une des entreprises ayant participé à l'étude avait aussi déjà adopté la méthode QEC et la méthode du FIOH dans le cadre de son programme d'amélioration continue. Aux fins de l'étude, elles ont toutes été appliquées à un échantillon de postes telles qu'elles seraient utilisées par un praticien et en respectant les recommandations proposées par les auteurs de ces méthodes.

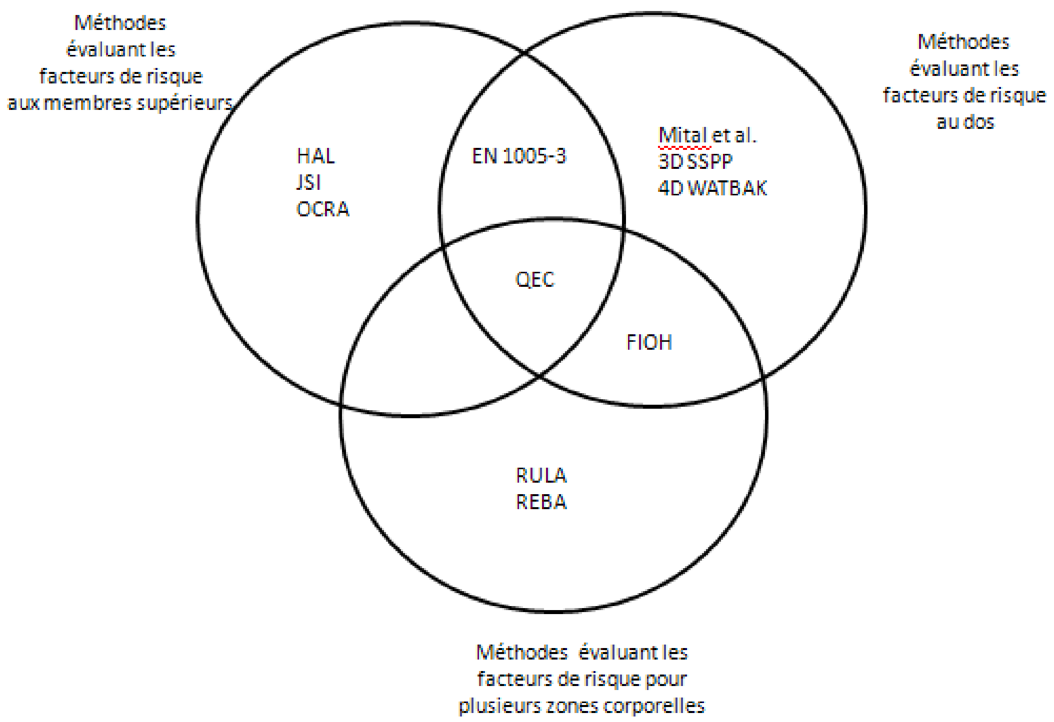

Figure 1.1 Les 11 méthodes d'évaluation des facteurs de risque de TMS classées selon trois groupes homogènes

La première étude, présentée au chapitre 3 de la thèse, présente une analyse des résultats obtenus à partir de six méthodes permettant d'évaluer les facteurs de risque de TMS au dos (*Ergonomic Workplace Analysis* du FIOH, *A Guide to Manual Materials Handling*, 2nd Edition Mital et al. 1997, QEC, 3D SSPP, 4D WATBAK et la norme EN 1005-3). La deuxième étude, présentée au quatrième chapitre, se penche sur deux groupes de méthodes : les méthodes permettant d'évaluer les facteurs de risque de façon plus globale ou pour plus d'une zone corporelle (*Ergonomic Workplace Analysis* du FIOH, QEC, REBA et RULA) ainsi que les méthodes permettant d'évaluer les facteurs de risque aux membres supérieurs (ACGIH HAL, Job Strain Index, OCRA, QEC et norme EN 1005-3). Les deux études permettent d'évaluer le niveau d'accord entre chacune des méthodes et proposent une analyse de ces résultats en lien avec les caractéristiques principales qui les distinguent. La méthode QEC permet non seulement d'obtenir un pointage global mais elle permet aussi une évaluation du poste en composantes distinctes. Entre autres, elle permet d'obtenir un pointage pour la région du dos et pour la région des membres supérieurs. *Ergonomic Workplace Analysis* du FIOH permet d'évaluer 14 aspects différents au poste de travail. L'aspect évaluant la levée de charge est comparé avec les autres méthodes d'évaluation du risque au dos. L'ensemble des aspects touchant de plus près les facteurs de risque de TMS sont regroupés puis comparés aux autres méthodes évaluant les facteurs de risque de façon plus globale. Ces deux méthodes se retrouvent donc dans les deux études. C'est aussi le cas de la norme EN 1005-3 qui permet une évaluation du risque pour différentes articulations. Appliquée à l'articulation de l'épaule et au tronc (niveau lombaire) pour cette étude, la norme se retrouve dans le groupe de méthodes permettant d'évaluer les facteurs de risque au dos et ceux aux membres supérieurs. Les méthodes auxquelles les deux premières études s’intéressent représentent un groupe n’ayant pas encore fait l’objet de comparaisons quantitatives entre elles dans la littérature scientifique.

Dans une troisième étude (chapitre 5), la recherche se penche de plus près sur une des méthodes prenant en compte l’opinion du travailleur dans l’évaluation du risque : *Ergonomic Workplace Analysis* développée par le FIOH. La perception du travailleur quant à la qualité ergonomique de son poste de travail et la nécessité d’y apporter des changements est également analysée en complément de la méthode du FIOH. L’objectif est de déterminer si le fait de déclarer des douleurs musculo-squelettiques peut avoir un lien avec la perception qu’a le travailleur des facteurs de risque liés à l’ergonomie à son poste de travail.

2.2 Terrains de recherche et collecte de données

Cette thèse s'inscrit dans le cadre d'un projet de cinq ans subventionné par l'Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST) portant sur la problématique des TMS (#099-468).

2.2.1 Terrains de recherche

Plusieurs terrains de recherche ont été mis à profit dans le cadre de ce projet. Les postes de travail d'où proviennent les données ont été choisis dans 18 usines appartenant à des secteurs d'activité économique variés : une grande entreprise manufacturière d'assemblage d'électroménagers, quatre usines de fabrication de produits de plastique et de composites, six pépinières forestières du secteur public, cinq usines du secteur de l'alimentation, une usine du secteur aérospatial et une usine de fabrication d'instruments de musique.

Aux prises avec des problèmes de TMS, ces milieux se sont révélés d'une richesse exceptionnelle pour réaliser une collecte de données d'une telle ampleur. Toutes les entreprises ayant pris part au projet de recherche ont été approchées soit par l'IRSST ou directement par la Chaire de recherche du Canada en ergonomie.

2.2.1.1 Principaux secteurs

Dans les trois secteurs présentés ci-dessous, les postes choisis pour effectuer la collecte de données avaient été identifiés directement par l'entreprise, suite à des plaintes rapportées par les travailleurs ou parce que l'entreprise jugeait ces postes à risque pour le développement de TMS, en plus d'être des postes où des changements améliorant la productivité devaient être apportés.

Six pépinières publiques produisent des millions de plants et de semis qui servent à reboiser des superficies de forêts québécoises. Elles comptent à elles seules plus de 1000 employés dans différentes régions du Québec. Leurs activités de production présentent des opérations difficiles pour les travailleurs, les exposant à plusieurs facteurs de risque (ex. postures contraignantes, travail au froid, manutention de charges, mouvements répétitifs). Le travail est très peu varié avec un temps de cycle moyen de 0,8 minute pour l'ensemble des postes étudiés, variant de 0,02 à 4,5 minutes. Répartis dans les six pépinières, 97 postes de travail ont été évalués dans le cadre de cette collecte de données.

L'entreprise d'assemblage d'électroménagers, comptant près de 100 employés, produit des cuisinières et des tables de cuisson. La prévalence des TMS y est très élevée (St-Vincent et al. 2011). Les postures statiques, le travail répétitif, les vibrations associées aux outils manuels et les applications de force observés pendant les activités d'assemblage (ex. vissage, branchement, emballage) se présentent comme les principaux facteurs de risque responsables des TMS. Au total, 49 postes de travail de cette entreprise ont été inclus dans la collecte de données. Ces postes avaient en moyenne des temps de cycle de 1,1 minute, variant de 0,1 à 3,4 minutes.

L'entreprise de fabrication de produits de plastique et de composites compte environ 150 à 250 employés dans chacune de ses quatre usines. Les 61 postes de travail évalués obligent à des opérations relativement variées avec un temps de cycle moyen de 90,7 minutes, variant de 0,6 à 1125 minutes. Les travailleurs étaient exposés à des facteurs de risque importants tels que les postures contraignantes, les vibrations associées aux outils et les applications de force.

2.2.1.2 Autres secteurs

Quant aux postes des autres secteurs étudiés (alimentation, aérospatiale et instruments de musique) ils ont été choisis parce qu'ils avaient été ciblés par les inspecteurs de la CSST comme ayant un historique de TMS. Onze de ces postes proviennent d'abattoirs et deux d'une usine de transformation des aliments pour un total de 13 postes dans le secteur de l'alimentation. Un des postes étudiés dans les abattoirs avait un temps de cycle de 5,2 minutes. Tous les autres postes de ce secteur comptent des cycles de travail très courts, donc du travail très répétitif, variant de 0,03 à 0,9 minutes, comparativement à l'usine de transformation (62,1 et 59,6 minutes) où c'est la manutention de charge qui est plus problématique. Pour ce qui est des deux autres secteurs, l'aérospatiale et les instruments de musique, les temps de cycle observés étaient plus longs. Les deux postes étudiés dans l'entreprise de fabrication des instruments de musique comptaient des temps de cycle de 47,2 et 100,2 minutes alors que les temps de cycles des deux postes du secteur de l'aérospatial étaient de 450 minutes.

Dans tous ces secteurs, les TMS représentaient un problème coûteux (Jallon 2011), d'où le désir des entreprises de participer à un tel projet de recherche s'inscrivant dans une démarche de mise en place d'interventions ergonomiques visant à transformer les postes de travail en vue d'y réduire les facteurs de risque de TMS.

2.2.2 Collecte de données

La collecte a permis de recueillir des données se rattachant à 224 postes de travail comptant 567 tâches. Au total, 516 travailleurs ont été interrogés dans le cadre de cette étude. La collecte de données s'est échelonnée sur une période de quatre ans.

Pour chaque poste de travail étudié, des mesures et un questionnaire (annexe A) ont permis d’obtenir l’information nécessaire pour réaliser l'évaluation au moyen des méthodes sélectionnées. Lorsque que cela était possible, plus d’un travailleur par poste se voyaient administrer le questionnaire. Les principales étapes de la collecte de données peuvent être résumées ainsi :

1) Un enregistrement de l’activité de travail réalisée au poste. Une dizaine de cycles de travail étaient filmés à chacun des postes lorsque possible ;
2) Une prise de différentes mesures : force à appliquer ou poids à manutentionner, mesuré à l’aide d’un dynamomètre (Chatillon DFIS 200) et/ou d’une balance électronique de table (KPS-50) ; niveau de bruit mesuré à l’aide d’un sonomètre (REED ST-850) ; niveau d’éclairage mesuré à l’aide d’un luxmètre (REED ST-1301) ; température mesurée à l’aide d’un psychromètre (REED LM-81HT) ; dimensions du poste de travail (hauteur de travail, position des mains, atteinte maximale, dégagement pour les jambes, déplacements) ;
3) Une entrevue semi-dirigée auprès de travailleurs du poste permettant de recueillir : les caractéristiques générales du sujet (âge, taille, poids corporel, années d’expérience au sein de l’entreprise et au poste de travail) ; l’évaluation du poste par le travailleur, requise pour les méthodes FIOH et QEC ; la perception du travailleur quant aux efforts à fournir au niveau des membres supérieurs (Borg 1998) ; la force maximale de préhension du travailleur, mesurée à l’aide d’un dynamomètre (Baseline Hydraulic Hand Dynamometer) ; la perception de la qualité ergonomique du poste de travail et la nécessité d’y apporter des changements, mesurés sur une échelle visuelle analogue (EVA) de 10 points ;

4) Finalement, un questionnaire tiré de l'enquête sociale et de santé du Québec de 1998 (ESS98), adapté du questionnaire nordique (Kuorinka et al. 1987), posait une série de questions à propos des douleurs ressenties à 11 parties du corps au cours des 12 derniers mois ainsi qu'au cours des sept derniers jours précédant la collecte de données. Le questionnaire nordique a été validé dans plusieurs études (Andersson et al. 1987 ; Ohlsson et al. 1994).

CHAPITRE 3: ARTICLE 1

COMPARING THE RESULTS OF SIX METHODS USED TO DETERMINE LOW BACK RISK

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Mots clés : ergonomics, assessment methods, musculoskeletal disorders, low back risk.

3.1 Abstract

The objective of this study is to compare the results obtained from methods most likely to be used by practitioners when assessing risk factors for musculoskeletal disorders of the back. Six methods were analyzed for the study: the QEC (Quick Exposure Check), the *Ergonomic Workplace Analysis* of the FIOH (Finnish Institute of Occupational Health), 3D SSPP (3D Static Strength Prediction Program), 4D WATBAK, *A Guide to Manual Materials Handling* by Mital et al. (1997) and the EN 1005-3 standard. The results are compared using three risk categories (low, moderate, high) and an exposure index. A total of 224 workstations involving 557 tasks in various industrial sectors were assessed using the six methods. Data were gathered using video and measurements taken at the workstations. A questionnaire was also administered to employees participating in the study. The findings reveal that the various methods differ in their analyses of the same workstation. Among the pairs of methods compared, 45% showed a difference of two risk level categories for at least 20% of the workstations. The 3D SSPP and 4D WATBAK methods identified over 85% of the workstations as low risk, while the EN 1005-3 standard, which is more conservative, identified nearly 90% as high risk.

Relevance to Industry

The study results provide information that can help practitioners and employers more effectively prevent musculoskeletal back injuries. Thanks to the data, there is a better understanding of how results can differ depending on the method chosen to assess low back risk.

3.2 Introduction

Musculoskeletal disorders (MSDs) of the back are a major problem in most industrialized countries. They not only require a significant financial outlay to compensate and care for injured workers, but MSD-associated injuries have a negative effect on workplace quality and productivity (Alzuheri et al., 2010 ; Boström et al., 2008 ; Martimo et al., 2009 ; NRC/IM, 2001). According to the 2000-2001 Canadian Community Health Survey (StatCan, 2001), injury prevalence is more significant for individuals in their thirties and forties. These injuries are affecting workers at the peak of their experience and activity level, with an impact that extends beyond the physical, to the personal and social. According to the World Health Organization, MSDs are the leading cause of workplace disability in developed countries (WHO, 2003). In the U.S., the Bureau of Labor Statistics reports that MSDs account for 29% of all lost-time work injuries.

Given the significant impacts of MSDs, industry needs to work on prevention. The scientific literature shows that intervention to reduce exposure to MSD risk factors is the best prevention strategy (Burdorf, 2010; Silverstein and Clark, 2004). To do this, companies must determine the MSD risk factors at their workstations. The National Institute for Occupational Safety and Health (NIOSH, 1997) and the National Research Council (NRC/IM, 2001) report a significant relationship between the development of MSDs and certain risk factors (loads handled, application of excessive force, awkward postures, vibration and repetition). According to several studies, these risk factors increase the risk of incurring a back injury (Hoogendoorn et al., 2000 ; Marras et al., 1995).

Questionnaires are still the MSD risk-factor assessment method most commonly used in the workplace because they are the least costly means of collecting a large amount of data from a substantial population. However, the rough data thus collected does not provide a sufficiently reliable estimate of worker exposure to risk factors (Barrero et al., 2009 ; Stock et al., 2005). To date, the ergonomic literature offers several other methods for assessing MSD risk-factor exposure (Burdorf, 2010 ; Dempsey et al., 2005; Imbeau and Fradet, 2004 ; Li and Buckle, 1999a). Some were developed with the intention of supporting industry-led MSD prevention efforts (Cole et al., 2003) and provide important guidelines for the implementation of occupational health and safety strategies. In other words, these methods are designed to help health and safety specialists and workplaces monitor workplace situations so that those that presenting risks are detected, ideally, before an injury occurs.

Unfortunately, few studies examine the differences in results that these methods produce (Marras et al., 1999 ; Waters et al., 1998). The lack of information about this in the literature stems from the difficulty of obtaining accurate and reliable exposure data (Jones and Kumar, 2007). Practitioners who work with these methods daily have neither the time, the resources or the expertise required to do such testing, which is rightly a matter for research. However, the selection of an appropriate assessment method is key to systematic and effective intervention.

Several studies have compared different methods. Those of David (2005), Kilbom (1994), Li and Buckle (1999a), Malchaire (2001) and Takala et al. (2010) review the literature on various MSD risk-factor assessment methods and qualitatively assess them. To date, few studies have provided quantitative analyses comparing low back risk-factor assessment methods. Burdorf and Laan (1991), Joseph et al. (2011), Lavender et al. (1999), Marklin and

Wilzbach (1999), Marras et al. (1999), Russell et al. (2007), van der Beek et al. (2005) and Waters et al. (1998). Comparisons have generally been made using small-size samples and/or samples from a single workplace.

Using a large collection of data gathered in industry over a five-year period, this study compares the findings obtained using six methods to assess risk to the back: QEC (David 2003 ; David et al. 2008 ; Li and Buckle, 1999b), the *Ergonomic Workplace Analysis* of the FIOH (Ahonen et al., 1989), the University of Michigan 3D Static Strength Prediction Program (versions 5.0 and 6.0), the University of Waterloo 4D WATBAK (version 1.3), *A Guide to Manual Materials Handling* (Mital et al., 1997) and the EN 1005-3 standard (CEN, 2002). The six methods were chosen for their ease of use and accessibility. These recent methods are likely to be used by non-researchers with varying levels of ergonomics expertise. Furthermore, for this study, all the methods were applied to the sample of workstations as a practitioner would use them and generally in accordance with the recommendations of the methods' authors.

Dempsey et al. (2005), in a survey of 308 Certified Professional Ergonomists (CPE), report that biomechanical models and psychophysical handling tables are among the most widely used methods. The NIOSH lifting equation (Waters et al., 1993) emerges as the method most commonly used by ergonomists to assess manual handling tasks. In this study, we have chosen to use the *A guide to Manual Materials Handling* (Mital et al. 1997) et al. (1997) tables rather than the NIOSH lifting equation or the Snook and Ciriello (1991) tables, because they offer the advantage from a practitioners' point of view of easily covering a wider range of handling activities in a single source: two-person lifting, lifting, pushing, pulling, carrying, one-handed and two-handed holding and materials handling in unusual postures. The NIOSH lifting equation cannot, for example, be used to assess a handling task wherein the worker must transport the load.

The six methods on which this study focuses have yet to be quantitatively compared in the scientific literature. An advantage of this study is that it was conducted on a large sample of tasks and workstations from a variety of workplaces.

3.3 Method

3.3.1 Sample

Data was collected from a sample of 224 workstations involving 567 tasks located in 18 plants from various industrial sectors: one appliance manufacturer, four plastics and composites manufacturers, six public-sector tree nurseries, five food processing plants, one aerospace manufacturer and one manufacturer of musical instruments (see Table 3.1). Given the small number of workstations in the food, aerospace and musical instrument plants, these sectors are shown as a single group (Other) to simplify the presentation of the findings. The workstations were chosen (a) because they were targeted by CSST (Québec's Workers' Compensation Board) inspectors as having a history of MSDs, (b) directly by the company itself following workers' complaints or (c) by the company as workstations at risk for causing MSDs that were also in need of changes to increase productivity. In all cases, the workstations were judged to be causes of concern with respect to MSDs. In this study, the assessments were performed on workstations whose cycle times ranged from 0.03 minutes to 18.75 hours (see 3.1) and the methods were compared using a widely varied time-cycle sample. The tree nursery and appliances sector workstations had the shortest cycle times (averaging 1.1 and 0.8 min), while those from the aerospace and plastics and composites manufacturing sectors were the longest (averaging 450 and 90.7 min). A total of 516 workers between 22 and 67 years of age participated in the study. Where workstations were used by more than one worker, measurements were taken from more than one worker. Since some positions were seasonal (i.e. nurseries), some workers occupied more than one workstation over the course of the data collection. They were therefore observed and questioned at more than one workstation.

Table 3.1

Number of workstations and average cycle time for each sector (min.)

Sector	Number of workstations	Avg.	SD	Min	Max
Aerospace*	2	450.0	0.0	450.0	450.0
Food*	13	9.9	22.7	0.03	62.1
Appliances	49	1.1	0.8	0.1	3.4
Musical instruments*	2	73.7	37.5	47.2	100.2
Nurseries	97	0.8	0.8	0.02	4.5
Plastics and composites	61	90.7	169.7	0.6	1125.0

* Sectors grouped under "Other" in this article.

3.3.2 Data collection

Measurements needed to complete the various risk-factor assessments for MSDs of the back were taken for each workstation studied. These measurements included the weight of the loads handled, the magnitude and direction of the force applied, working heights, any significant transport/pushing/pulling distances or displacements and shift length. Finally, a video recording of ten work cycles was taken when possible at each workstation for a time-motion study using the Video Event Analysis application (Chappe, 2006). The time-motion studies provided work-cycle durations, task distribution and movement frequency for the workstations studied. For workstations with very long cycle times, the most critical tasks of the cycle where observed.

A questionnaire collecting the information required for the QEC and FIOH assessment methods, which require the worker's opinion, was administered to workstation employees. In cases with more than one worker at a workstation, more than one interview was conducted to collect the information.

Following data collection in the company, workstation assessments were conducted by graduate students with training in occupational ergonomics or by ergonomists experienced in the six methods studied in this paper.

The postures selected were chosen using the workstation video. When recording it, the ergonomist ensured that the camera was well-positioned to record the worker's entire body so the posture could be accurately replicated in 3D SSPP and 4D WATBAK. The postures selected for analysis were those identified by the ergonomists as the most demanding (awkward posture and/or force application) at the workstation. One to four postures per workstation, depending on the variability of the work, were programmed for analysis in 3D SSPP.

3.3.3 Methods for assessing low back risk

(1) QEC. The *Quick Exposure Check* (QEC) is posture-based and used to assess a workstation for MSD risk factors to the back, arms, neck and upper extremities. Combining the observer's assessment with the worker's answers to closed questions, this method produces a risk level for each of the targeted areas (back, shoulder/arm, wrist/hand and neck). The final score also takes psychosocial risk factors and exposure to vibration into account (David et al., 2003 ; David et al. 2008 ; Li and Buckle, 1999b). Although this method is a comprehensive assessment tool for MSD risk factors, combining the assessment of risk factors to the back and upper extremities with a psychosocial risk-factor assessment, we wanted to see how its assessment of low back risk compared to that of other methods more specific to this area of the body. Therefore, only the back index was used (QEC Back). This index takes into account the load handled, posture, frequency of back movement and duration of work.

(2) FIOH. The *Ergonomic Workplace Analysis* method developed by the Finnish Institute of Occupational Health (FIOH) (Ahonen et al., 1989) includes both experts and workers in the assessment of the workstation. It provides a wide-ranging ergonomic analysis of 14 different items: (1) workstation site, (2) general physical activity, (3) lifting, (4) working posture and movements, (5) accident risk, (6) job content, (7) job constraints, (8) personal contacts and communication, (9) decision-making, (10) repetitiveness, (11) attentiveness, (12) lighting, (13) thermal environment and (14) noise. Experts and workers have to complete an assessment of the 14 items. Workers' subjective evaluation is obtained using a four grade scale (1 to 4): very poor, poor, good, and very good. When the worker rates his workstation as *very poor*, he/she considers that the conditions are far from ideal in terms of MSD risk factors. The expert has to evaluate the workstation using a four or five grade scale, depending on the items being assessed, where a score of four or five means that the conditions present a risk for the worker and a score of one means that the conditions are deemed acceptable or safe. For this study, the score was determined by combining the worker's and observer's assessments of each item into a final score of 10 points. For the FIOH method, the load-handling assessment sub-score

(FIOH Back [3]) was used, which takes the horizontal distance and weight of the load into account.

***(3) A Guide to Manual Materials Handling*.** This guide by Mital et al. (1997) contains tables with proposed design criteria to accommodate a certain percentage of the population during manual handling tasks or those requiring the application of force. Recommended loads and force have been determined using a psychophysical approach that integrates the biomechanical and physiological criteria appropriate for the type of handling. The recommended loads depend on the type of handling activity and conditions in which it is performed, and can be adjusted according to certain number of characteristics (duration, coupling, heat stress, asymmetrical lifting, limited headroom, load asymmetry and load placement clearance). They determine whether a handling task is acceptable, targeting the maximum acceptable weight for a certain percentage of the population. The larger the proportion of the population accommodated, the safer the activity. These tables are similar to those proposed by Snook and Ciriello (1991). As noted above, the advantage of the Mital et al. (1997) guide is that it can be used to quickly and easily assess a wider range of handling activities.

(4) 3D SSPP. The *Three-Dimensional Static Strength Prediction Program* (versions 5 and 6) software from the University of Michigan Center for Ergonomics (2001) can be used to assess the static biomechanical limitations of situations involving the use of force. After being videotaped, a selected worker posture is then reproduced in 3D SSPP and analyzed with the model, which returns the joint loading moments. These values can then be compared to population data to estimate the percentage of the population capable of this level of exertion. The program can also be used to estimate the compression force on the L5-S1 intervertebral disc and the shear force at the lower back. For this study, the choice was made to compare the three indices obtained from the 3D SSPP software (spinal moment, compression and total shear) separately, since this method does not provide a combined or global risk index.

(5) 4D WATBAK. 4D WATBAK software (version 1.3) from Ergowatch at the University of Waterloo (1998) is used to assess various handling activities and calculate joint loading. Compression and shear force on the lower back (L4-L5 disc) are calculated using a two-dimensional biomechanical model. Each work posture is reproduced from a video of the worker. In addition to being only two dimensions, it also differs from 3D SSPP by taking into account the frequency and duration of postures, which means it can estimate the cumulative loads experienced at the joints and lumbar area during an eight-hour shift. The *Combined Low Back Pain Reporting Index* (LBP Index) (Norman et al., 1998) is an index that takes into account both peak and cumulative loads. It can be used to estimate the probability of an individual developing back pain if he/she continues to perform the task being analyzed. A time-motion study must be done in conjunction with 4D WATBAK to determine the duration and frequency of each posture during a shift.

(6) EN 1005-3. The European Standard, *Safety of machinery Human physical performance Part 3*: *Recommended force limits for machinery operation* (CEN, 2002) is a general-purpose method that helps designers assess the risk related to force application during work. The acceptable force is obtained by applying various multipliers, i.e., speed, duration and frequency of actions, to a basic capability, which is represented by the maximum capability of the 15th percentile worker. The 3D SSPP population capability distribution parameters were used to obtain the basic value for the low-back (i.e., the 15th

percentile maximum moment for the target worker population ; see EN 1005-3). The reduced value was obtained by following the calculation steps using the standard's proposed coefficients.

3.3.4 Method comparison criteria

To compare the methods under study, which do not use the same types of index, each method's results were categorized according to three risk levels (low, moderate, high), using the threshold values described in Table 3.2. These threshold values were either proposed by the authors of the methods or follow design recommendations put forth in the recent ergonomics literature.

Table 3.2

Threshold values for comparing the results of the six methods used to determine low back risk.

Method	Low	Moderate	High
QEC Back	10 - 20	21 - 30	31 - 56
FIOH Back	< 2	≥ 2, < 6	6 - 10
Mital et al. (1997)	≤ MAWL	> MAWL, < 2 x MAWL	≥ 2 x MAWL
3D SSPP Moment	$\leq R_{SDL}$	$> R_{SDL}, < R_{SUL}$	$\geq R_{SUL}$
3D SSPP Compression (N)	< 3400	≥ 3400, < 6400	≥ 6400
3D SSPP Total Shear (N)	≤ 330	> 330, < 660	≥ 660
4D WATBAK Moment*	$\leq R_{SDL}$	$> R_{SDL} < R_{SUL}$	$\geq R_{SUL}$
4D WATBAK Compression (N)	< 3400	≥ 3400, < 6400	≥ 6400
4D WATBAK Joint Shear (N)	≤ 330	> 330, < 660	≥ 660
4D WATBAK LBP Index	≤ 0.15	> 0.15, < 0.85	≥ 0.85
EN 1005-3	≤ 0.5	> 0.5, ≤ 0.7	> 0.7

* R_{SDL} = Resulting moment/25th percentile maximum moment ; R_{SUL}= Resulting moment/99th percentile maximum moment (see text for details)

(1) QEC Back. The QEC method uses four risk categories. To allow comparisons with the other methods which only use three, the high" and "very high" risk categories proposed by the authors (David et al., 2008) were grouped into a single category. When more than one worker could evaluate the same workstation, the assessments were averaged to obtain a single QEC Back index per workstation.

(2) FIOH Back. The FIOH method uses four risk categories for load handling. To allow comparisons with the other methods which only use three, risk categories 3 and 4 were combined into a single category. When more than one worker could evaluate the same workstation, the assessments were averaged to obtain a single FIOH Back index per workstation.

(3) A Guide to Manual Materials Handling Mital et al. (1997) The exposure index was calculated to accommodate 90% of the female population. A load handled (actual value) exceeding the value specified in the table indicates an exposure index greater than one. A factor of 2 was used to determine the upper-limit threshold value (high risk). In the Mital et al. (1997) lifting tables, the maximum acceptable weight of lift (*MAWL*) value that is safe for 10% of the population is usually around twice the 90% population MAWL. Therefore, a real-load value twice as high as the MAWL value safe for 90% of the population was deemed to represent a high risk, that is a risk for a large majority of the population. The 10% high risk indication is consistent with the *Liberty Mutual Manual Materials Handling Guidelines* (page i) recommendation to practitioners: "Tasks having population percentages of less than 10% should be prioritized for task redesign." Ten percent (10%) is close to the Maximum Permissible Limit (MPL) risk of the 1981 NIOSH lifting guide, or three times the Recommended Weight Limit (RWL) of the 1991 NIOSH lifting equation, for which only about 13% of the general population is considered not at risk (1% of women and 25% of men, or about 13% for a 50/50 mixed group of workers) (Waters et al., 1993).

(4) 3D SSPP. The threshold values used for L5/S1 (N) disc compression are based on the Back Compression Design Limit (BCDL) and the Back Compression Upper Limit (BCUL) from the *Work Practices Guide for Manual Lifting* (NIOSH, 1981). The 3400 N (BCDL) value is the criterion for protecting 99% of the male population and 75% of the female population. The upper limit of 6400 N, the moderate-risk category (BCUL), protects 25% of men and 1% of women. Risk levels for moments at the back during flexion/extension in the sagittal plane were determined using the Strength Design Limit (SDL) and Strength Upper Limit (SUL), also documented in the *Work Practices Guide for Manual Lifting* (NIOSH, 1981 ; Waters et al., 1993). For the purposes of this study, the SDL is the 25th distribution percentile of the maximum moment value for a female population based on the Stobbe (1980) equations, while the SUL is the 99th percentile. Risk category thresholds are calculated by dividing the real moment by the SDL value for the low-risk category and by the SUL for the high-risk category. The shear threshold values are the Action Limit (AL) and Maximum Permissible Limit (MPL) from the University of Waterloo (McGill et al., 1998). All analyses were performed using 50th percentile anthropometric data for women. For workstations with more than one task, the maximum values of low back moment, compression and total shear were used for comparisons between methods. Peak load values represent the highest value calculated across all analyzed postures.

(5) 4D WATBAK. The threshold values used for L4/L5 disc compression are based on the same BCDL and BCUL used with 3D SSPP. Risk levels for low back moments at L4/L5 during flexion/extension in the sagittal plane were determined using the SDL and SUL percentages, as noted above for 3D SSPP. The maximum moment threshold values recommended by NIOSH were calculated using the force distribution parameters for the selected population, which are available in 4D WATBAK and come from the work of Troup and Chapman (1969). The joint shear threshold values were determined using the same criteria as for 3D SSPP (total shear). All analyses were performed using 50th percentile women anthropometric data. The posture (position of the head, trunk, arms, hands and legs) and application of force analyzed in 4D WATBAK were the same as those used in 3D SSPP. Once the joint angle values in the sagittal plane obtained from 3D SSPP were reproduced in the biomechanical model, they were copied into 4D WATBAK. As in 3D SSPP, for workstations with more than one task, the maximum values of low back moment, compression and joint shear were used to compare the methods. The threshold values used to classify risk according to the Combined LBP Index were determined using recommendations from the EN 1005-3 standard that are consistent with those used in the Mital et al. (1997) guide, as discussed above. Therefore, a threshold value less than or equal to 0.15 protects a majority of the worker population, while a threshold value greater than or equal to 0.85 represents a risk for a large proportion of the population.

(6) EN 1005-3. As specified in the standard, the exposure index was calculated to protect 85% of the female population. The 15th percentile of the female distribution of the maximum low back moment value during flexion/extension in the sagittal plane (i.e., the one with the lowest able population percentage) was used as the basic-force reference for calculating the reduced force using the multipliers supplied by the standard. The 15th distribution percentile value was obtained from 3D SSPP's Strength Capabilities Report (Stobbe, 1980). If the ratio between the actual value and that obtained using the standard was higher than 0.5, the task was deemed to present a moderate risk. The risk was considered high when this ratio was greater than 0.7 (EN, 2002). In the case of workstations with more than one task, the task for which the risk was highest according to the standard was used for the comparisons.

Table 3.3 shows the number of tasks and workstations assessed using each method. The number of tasks may differ from the number of workstations evaluated, as some methods can be used to evaluate several tasks per station whereas others provide a single index per workstation. If a method is shown as having fewer than 224 workstations (the total number included in the study), this is because the data collection turned up missing, unusable or irrelevant information. For example, in the case of the Mital et al. (1997) method, if the application of force was negligible or no manual handling task was carried out at the workstation, then the method could not be used, which created a sample of fewer than 224 workstations.

Table 3.3

Total number of workstations and tasks evaluated using the six methods

Method	No. of workstations	No. of tasks
QEC Back	217	-
FIOH Back	220	-
Mital et al. (1997)	167	-
3D SSPP Moment	220	486
3D SSPP Compression	220	557
3D SSPP Total Shear	220	567
4D WATBAK Moment	165	437
4D WATBAK Compression	165	446
4D WATBAK Joint Shear	165	464
4D WATBAK LBP Index	119	-
EN 1005-3	167	227
TOTAL	**224**	**567**

3.3.5 Data analysis

JMP statistical software for Windows (SAS Institute Inc., version 9.0.2) was used for the data analysis, which included descriptive statistics, the Tukey-Kramer HSD test, Pearson's intercorrelations and two-by-two contingency tables.

The Tukey-Kramer HSD parametric test was selected for the comparisons because of the large number of observations and the equal variance of the distributions (homoscedasticity). The Tukey-Kramer method is conservative when sample sizes are unequal. The Bonferroni criterion was applied to control the risk of alpha inflation, given the multiple comparisons. Results showing values above the significance threshold ($p < 0.05$) were considered statistically insignificant. P-values located between the threshold of significance $p < 0.05$ and the threshold value determined by the Bonferroni criterion ($p < 0.05/k$), identified comparison pairs with a high likelihood of statistical significance in the absence of multiple comparisons (i.e., protection against alpha error inflation). Correlation-coefficients (Pearson's) helped identify the degree of association between two compared methods.

3.4 Results

3.4.1 Risk classification

Presentation of the results by risk category clearly illustrates the differences between the methods (Figure 1). The first thing one notices is the high proportion (88.1%) of workstations considered to be high risk under the EN 1005-3 standard. In the case of methods that use biomechanical modelling software, the assessments are not as harsh. 3D SSPP and 4D WATBAK report similar risk levels, with compression force assessed as low risk at 97.5% and 85%, respectively, and shear force at 92.8% and 84.6%. The 3D SSPP and 4D WATBAK results for low back moments were also similar, with more than 97% of workstations classified as low risk. As for the LBP index, it classified most workstations as moderate risk (82.4%). The use of the Mital et al. (1997) guide assessed 53.3% of the sample workstations as low risk and 18% as high risk. The QEC method identified 47.9% of the workstations as high risk and 6.9% as low risk. The FIOH method found that a majority of assessments indicated a moderate risk (59.6%) and 10% of them a low risk.

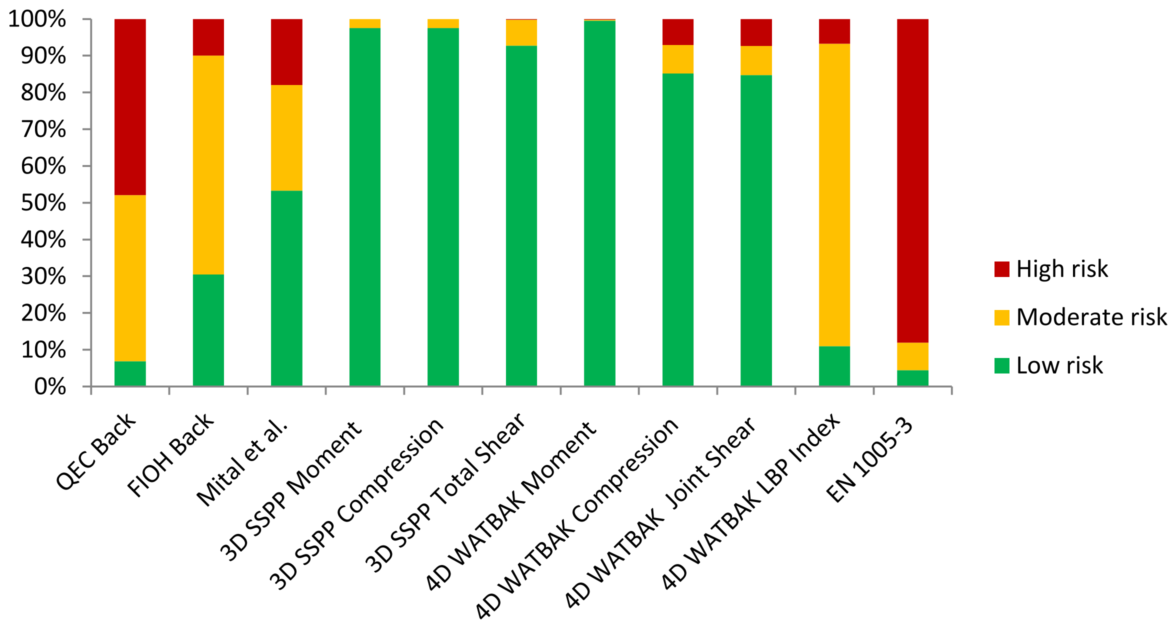

Figure 3.1 Distribution of risk levels for all workstations, based on the 11 indices obtained from the six evaluation methods.

3.4.2 Agreement and intercorrelation between methods

The creation of two-by-two contingency tables shows paired comparisons of the risk levels obtained using each of the six methods (see Table 3.4). The values in the first column show the percentage of discrepancy for one risk category for the selected pair. The second column shows the percentage of discrepancy for two risk categories. The third column shows a mean discrepancy score for the pair. This score is calculated by combining the discrepancy score for one risk category with the discrepancy score for two risk categories multiplied by two. No pair of methods is in complete agreement. The lowest discrepancy scores and the highest correlations were found between the indices of the two biomechanical models, with the exception of the LBP Index. The most significant differences were between 3D SSPP and EN 1005-3.

The 4D WATBAK and 3D SSPP indices, with the exception of LBP, were the methods that assessed the most tasks as being in the same risk category, with a mean discrepancy score ranging from 2.29 to 44.31. The two methods, which use software based on biomechanical calculations, came to the same conclusion between 76.05% and 97.94% of the time for all the indices used (inter or intra-method), with the exception of the 3D SSPP compression index and the 4D WATBAK joint shear index, which had a discrepancy score of 44.31%. The 3D SSPP compression and total shear indices had the highest correlation (r=0.78) with the 4D WATBAK indices. The LBP index has the strongest correlation with the 4D WATBAK compression index (r=0.72) and the weakest with the FIOH Back (r=0.24).

All the methods differed significantly (48.37 to 182.96) when compared with the EN 1005-3 standard, which is the most stringent in its workstation classification. For example, in 61% to 85% of cases, a workstation considered low risk by 3D SSPP or 4D WATBAK was assessed as high risk (a difference of two risk categories) when using EN 1005-3. The methods furthest from one another in their risk assessment results are the EN 1005-3 standard and the 3D SSPP low back moment. In 83.19% of cases, the EN 1005-3 standard classified a workstation as high risk, while the 3D SSPP considered it low risk.

The QEC method is the method least at variance with the EN 1005-3 standard, agreeing on the risk level classification 56.6% of the time. The QEC back index also appears to be more stringent than the other methods, with the exception of the EN 1005-3 standard. It notes a higher risk level for compression in proportions ranging from 44.7%, when compared with the FIOH method, to 92.5% when compared with 4D WATBAK. The Mital et al. (1997) guide, meanwhile, emerges as the method most likely to agree with 3D SSPP and 4D WATBAK. If 3D SSPP and 4D WATBAK are not taken into account, then Mital et al. (1997) has the strongest correlation (r=0.58) with the FIOH Back index. As for Mital et al. (1997) and the EN 1005-3 standard, this pair shows the weakest correlation (r=0.07).

Table 3.4

Paired comparisons of risk levels obtained using each of the six methods and pairwise correlation

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
QEC Back/FIOH Back (N=217)	53.91	6.45	66.81	0.41***
QEC Back/Mital et al. (N=162)	52.46	22.84	98.14	0.22**
QEC Back/3D SSPP Moment (N=207)	51.21	38.65	**128.51**	0.36***
QEC Back/3D SSPP Compression (N=214)	51.87	39.72	**131.31**	0.45***
QEC Back/3D SSPP Total Shear (N=214)	55.61	32.24	**120.09**	0.41***
QEC Back/4D WATBAK Moment (N=159)	47.17	45.91	**138.99**	0.33***
QEC Back/4D WATBAK Compression (N=160)	50.63	41.88	**134.39**	0.48***
QEC Back/4D WATBAK Joint Shear (N=160)	43.77	29.38	102.53	0.30***
QEC Back/EN 1005-3 (N=122)	38.53	4.92	48.37	0.30***

Table 3.4 (Continued)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
FIOH Back/Mital et al. (N=163)	47.85	1.84	51.53	0.58***
FIOH Back/3D SSPP Moment (N=209)	56.94	7.66	64.6	0.25***
FIOH Back/3D SSPP Compression (N=216)	59.26	7.41	74.88	0.36***
FIOH Back/3D SSPP Total Shear (N=216)	54.63	6.02	66.67	0.33***
FIOH Back/4D WATBAK Moment (N=160)	65.64	8.13	81.9	0.37***
FIOH Back/4D WATBAK Compression (N=161)	65.21	6.21	77.63	0.45***
FIOH Back/4D WATBAK Joint Shear (N=161)	58.38	9.31	77.01	0.12
FIOH Back/EN 1005-3 (N=123)	65.05	19.51	103.07	0.16

Table 3.4 (Continued)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
Mital et al./3D SSPP Moment (N=162)	42.59	3.7	49.99	0.24**
Mital et al./3D SSPP Compression (N=165)	38.79	4.24	47.27	0.39***
Mital et al./ 3D SSPP Total Shear (N=165)	36.97	2.42	41.81	0.37***
Mital et al./ 4D WATBAK Moment (N=139)	42.45	7.91	58.27	0.41***
Mital et al./ 4D WATBAK Compression (N=139)	44.61	5.04	54.69	0.49***
Mital et al./ 4D WATBAK Joint Shear (N=139)	43.89	12.95	69.79	0.17*
Mital et al./ EN 1005-3 (N=112)	51.79	40.18	**132.15**	0.07

Table 3.4 (Continued)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
3D SSPP Moment/3D SSPP Compression (N=156)	5.77	0	5.77	0.72***
3D SSPP Moment/3D SSPP Total Shear (N=156)	12.18	0	12.18	0.60***
3D SSPP Moment/4D WATBAK Moment (N=160)	9.57	0	9.57	0.50***
3D SSPP Moment/4D WATBAK Compression (N=161)	8.53	0	8.53	0.69***
3D SSPP Moment/4D WATBAK Joint Shear (N=161)	15.62	8.33	32.28	0.41***
3D SSPP Moment/EN 1005-3 (N=127)	12.5	85.23	**182.96**	0.28**
3D SSPP Compression/3D SSPP Total Shear (N=156)	6.83	0	6.83	0.78***
3D SSPP Compression/4D WATBAK Moment (N=164)	2.44	0.41	3.26	0.61***
3D SSPP Compression/4D WATBAK Compression (N=165)	2.4	0	2.4	0.75***
3D SSPP Compression/4D WATBAK Joint Shear (N=175)	39.37	2.47	44.31	0.47***

Table 3.4 (Continued)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
3D SSPP Compression/EN 1005-3 (N=127)	12.39	83.19	**178.77**	0.38***
3D SSPP Total Shear/4D WATBAK Moment (N=164)	7.32	0.82	8.96	0.59***
3D SSPP Total Shear/4D WATBAK Compression (N=165)	6.4	0.4	7.2	0.66***
3D SSPP Total Shear/4D WATBAK Joint Shear (N=175)	14	0	14	0.55***
3D SSPP Total Shear/EN 1005-3 (N=127)	19.47	75.66	**170.79**	0.30***

Table 3.4 (Continued)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
4D WATBAK Moment/4D WATBAK Compression (N=164)	7.8	7.8	23.4	0.76***
4D WATBAK Moment/4D WATBAK Joint Shear (N=164)	1.83	0.23	2.29	0.39***
4D WATBAK Moment/EN 1005-3 (N=68)	13.33	78.1	**169.53**	0.18*
4D WATBAK Compression/4D WATBAK Joint Shear (N=165)	9.41	7.17	23.75	0.44***
4D WATBAK Compression/EN 1005-3 (N=69)	17.6	74.07	**165.74**	0.39***
4D WATBAK Joint Shear/EN 1005-3 (N=69)	26.85	61.11	**149.07**	0.11
4D WATBAK L.B.P. Index/QEC Back (N=118)	53.39	2.54	58.47	0.56***
4D WATBAK L.B.P. Index/FIOH Back (N=118)	35.59	2.54	40.67	0.24**
4D WATBAK L.B.P. Index/Mital et al. (N=94)	57.4	3.19	63.78	0.34***
4D WATBAK L.B.P. Index/3D SSPP Moment (N=115)	74.78	3.48	81.74	0.72***

Table 3.4 (End)

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Pairwise correlation coefficient
4D WATBAK L.B.P. Index/3D SSPP Compression (N=119)	77.31	4.2	85.71	0.71***
4D WATBAK L.B.P. Index/3D SSPP Total Shear (N=119)	68.9	2.52	73.94	0.66***
4D WATBAK L.B.P. Index/4D WATBAK Moment (N=118)	81.36	6.68	94.72	0.51***
4D WATBAK L.B.P. Index/4D WATBAK Compression (N=119)	78.99	5.88	90.75	0.72***
4D WATBAK L.B.P. Index/4DWatback Joint Shear (N=119)	68.9	0.84	70.58	0.63***
4D WATBAK L.B.P. Index/EN 1005-3 (N=82)	89.03	2.44	93.91	0.26***

In bold: discrepancy score > 120

Significance thresholds: *$p < 0.05$ **$p < 0.01$ ***$p < 0.0001$

3.4.3 Comparison of averages between sectors

Table 3.5 presents the results of the Tukey-Kramer HSD test, used to determine which pairs of sectors had different average results using the six methods. Any p-values that are below the threshold adjusted for Bonferroni are listed in bold and indicated by two asterisks (**), while any p-values located between the significance thresholds $0.05 > p > 0.0083$ are identified by one asterisk (*). The findings show statistically significant differences between certain pairs of sectors. The tree nursery industry emerges as the one whose means most often differ from those in other sectors. Among other things, the findings show statistically significant differences between the means obtained using FIOH Back, Mital et al. (1997) , 3D SSPP, 4D WATBAK and EN 1005-3.

Table 3.5

P-values of Tukey-Kramer test to compare sectors and risk output scores

Sector / Risk output scores	QEC Back	FIOH Back	Mital et al. (1997)	3DSSP Moment	3D SSPP Compression	3D SSPP Total Shear	4D WATBAK Moment	4D WATBAK Compression	4D WATBAK Joint Shear	4DWatback L.B.P. Index	EN 1005-3
Tree nursery/Appliances	0.099	0.610	0.696	**0.000****	**0.000****	**0.000****	0.304	0.404	0.206	n⁄a	0.924
Tree nursery/Other	0.460	0.937	0.244	**0.001***	**0.001****	0.423	0.037*	0.148	0.062	**0.004****	0.219
Tree nursery/Plastics/composites	0.199	0.264	0.087	**0.000****	**0.000****	**0.000****	**0.000****	**0.000****	**0.004****	**0.000****	**0.000****
Plastics/composites/Appliances	0.970	0.037*	0.045*	0.626	0.671	0.989	0.988	0.991	0.941	n⁄a	0.253
Plastics/composites/Other	0.996	0.937	0.997	0.929	0.823	0.330	0.996	0.962	0.952	0.984	1.000
Other/Appliances	1.000	0.553	0.096	0.997	1.000	0.541	0.999	1.000	0.998	n⁄a	0.391

*P-values between 0.05 and 0.05/6 = 0.0083
** (in bold) significant p-values (Bonferroni correction)

3.4.4 Risk index

Table 3.6 shows the average exposure index for each result obtained using the six methods. The results were standardized into an exposure index using the threshold value of the low risk category in Table 3.2 (Russell et al., 2007) since the methods do not use the same type of measurement scale. An exposure index of 1.0 indicates a safe level of exposure (i.e., the load handled is within the recommended weight). An index higher than 1.0 indicates that the exposure risk factor is higher than recommended. Once again, the EN 1005-3 standard emerges as the method with the highest average exposure index (6.4 ± 8.1) as well as the widest range of values (0.1 to 86.1). The average exposure indices for 3D SSPP and 4D WATBAK did not exceed 1.0. QEC Back recorded an average exposure index of 1.54 ± 0.36, similar to that of FIOH Back, which was 1.58 ± 0.98. Workstations assessed using the Mital et al. (1997) method generated an average exposure index of 1.21 ± 0.98.

Table 3.6

Average exposure index for each result obtained using the six methods

Methods	Average	Standard deviation	Min	Max
QEC Back	1.54	0.36	0.5	2.65
FIOH Back	1.58	0.98	0	4.15
Mital et al.	1.21	0.98	0	5.83
3D SSPP Moment	0.47	0.3	0	1.97
3D SSPP Compression	0.44	0.24	0.07	1.49
3D SSPP Total Shear	0.52	0.32	0.02	2.02
4D WATBAK Moment	0.27	0.21	0	2.09
4D WATBAK Compression	0.4	0.23	0.1	1.32
4D WATBAK Joint Shear	0.52	0.74	0	3.62
4D WATBAK LBP Index	0.436	0.251	0.11	0.97
EN 1005-3	6.4	8.1	0.1	86.1

3.4.5 Prioritization identified by the methods

From the entire sample, 67 workstations were selected because they had been assessed by all eleven indices used by the six methods. From this subgroup, the priority workstations, i.e. those with a high risk level, were identified by each method. Table 3.7 compares the number of workstations judged as priorities by each index. When reading the table from top to bottom, the figures in bold represent the number of workstations identified as priorities by a particular index or method, while the other figures in the same column show how many of the same workstations were also identified as priorities by the other methods. If an index or method is missing from the table, this means that it did not identify any of the workstations from the sample of 67 as a priority. This was the case, for example, for the 3D SSPP Compression index. If the QEC method is applied to this sample of 67 workstations, it would identify 41 of them as priorities, while FIOH and Mital et al. (1997) would only recognize 10 and 13, respectively, of the QEC's 41 found priorities. If the Mital et al. (1997) index is applied, the difference is smaller as the FIOH and QEC indices would recognize 9 and 13, respectively, of the 19 workstations identified by Mital et al. (1997) Of the 10 workstations identified as priorities by the FIOH method, QEC identifies the same 10, and Mital et al. (1997), drops one. Of the results obtained with 3D SSPP and 4D WATBAK, only the Joint Shear index stands out, identifying 11 of the 67 workstations as priorities. The QEC Back index identifies eight of the 11.

Table 3.7

Number of workstations identified as priorities, by index (n = 67)

	QEC Back	FIOH Back	Mital et al. (1997)	3DSSPP Total Shear	4Dwatbak Moment	4DWATBAKCompression	4DWatbak Joint Shear	4DWatbal L.B.P. Index	EN 1005-3
QEC Back	**41**	10	13	1	0	0	8	3	41
FIOH Back	10	**10**	9	0	1	0	1	1	10
Mital et al.	13	9	**19**	0	1	0	2	2	18
3DSSPP Total Shear	1	0	0	**1**	0	0	0	0	1
4DWATBAK Moment	0	1	1	0	**1**	0	0	0	0
4DWATBAK Compression	0	1	1	0	1	**1**	0	0	0
4DWATBAK Joint Shear	8	1	2	0	0	1	**11**	4	11
4DWatbak L.B.P. Index	3	1	2	0	0	0	4	**4**	4
EN 1005-3	41	10	18	1	0	0	11	4	**63**

From the sample of 67 workstations that were all assessed using the eleven indices of the six methods, the number of workstations identified as priorities (at high risk) by more than one method was calculated. The first column of Table 3.8 shows the number of workstations identified as priorities by between zero and six indices. The second column does the same exercise, excluding the EN 1005-3 standard. In the workstation sample presented here, 94% of the workstations are considered priorities according to the EN 1005-3 standard (see Table 3.7). When this method is excluded, 25 of the 67 workstations are prioritized by only one index, while 24 are identified as priorities by at least two indices. Only one workstation was identified by five indices. No single workstation was identified by all eleven indices of the six methods.

Table 3.8

Number of workstations identified as priorities, by number of indices (n = 67)

Number of indices	Number of workstations	Number of workstations (excluding the EN-1005-3 standard)
0	3	18
1	15	25
2	26	12
3	11	11
4	11	-
5	-	1
6	1	-

3.5 Discussion

3.5.1 Risk assessment

Our analysis of the six methods and their 11 indices shows that, when compared, some methods produce conflicting results. The EN 1005-3 standard seems the most stringent, classifying nearly nine out of ten workstations in the high risk category. The 3D SSPP and 4D WATBAK methods are less conservative or strict, classifying more than eight out of ten workstations as low risk, with the exception of the 4D WATBAK LBP Index, which ranks eight out of ten workstations as moderate risk. For the entire sample, 97.5% of the maximum lumbar compression values measured at the workstations using 3D SSPP were classified as low risk. Lavender et al. (1999) reported similar results for compressive force in a study comparing five methods of assessing low back risk. In their study, 96% of workstations were categorized as low risk. Russell et al. (2007) also report obtaining similar results using 3D SSPP. For 4D WATBAK, we note the same trend with 85.1% of the measurements of compression falling into the low-risk category. A large proportion of shear values are also found to be low risk according to 3D SSPP and 4D WATBAK, which recorded results of 92.8% and 84.8%, respectively. A workstation analysis using the EN 1005-3 standard and 3D SSPP or 4D WATBAK might generate conflicting results. 3D SSPP and 4D WATBAK would not categorize the workstation as high risk while the standard would indicate the opposite.

3.5.2 Comparisons between sectors

With the exception of "Other", all the sectors show a statistically significant variance from the tree nursery sector for the averages obtained using the 3D SSPP and 4D WATBAK risk output scores. These results can be explained by the work postures adopted in nurseries, which are among the most awkward in our sample and thus generate higher risk indices in 3D SSPP. Postures involving squatting, sitting on the ground, lumbar flexion greater than 90° and twisting were regularly observed in this sector. The 3D SSPP three-dimensional model proved to the one best able to reproduce the more complex postures common in the tree nursery sector (Bone et al. 1990). In contrast, in the other more traditional manufacturing sectors, standing was the most commonly observed posture (e.g. in appliances). The 4D WATBAK 2D model seemed to be unable to detect the awkward postures in either the tree nursery or appliances sector.

With respect to differences between the tree nursery and plastics/composites sectors, it appears that those detected by 4D WATBAK related to the loads handled—light in the nurseries and heavy in plastics/composites—rather than the postures.

The differences between the tree nursery and plastics/composites sectors detected by the EN 1005-3 standard related to cycle times, which were very short in the tree nursery sector (avg. 0.8 min.), and much longer in the plastics-composites sector (avg. 90.7 min). These two workstation groups represented extremes in terms of average cycle time.

As for differences between the plastics/composites and appliances sectors, according to the FIOH Back and Mital et al. (1997) indices, the loads handled (or force applied) differed between the two. The appliances sector recorded less strenuous handling tasks and applications of force than those found in the plastics/composites sector.

3.5.3 Agreement between methods

Of the pairs compared, 45% showed differences of two risk levels for at least 20% of the workstations (see Table 3.4). In concrete terms, this means that when interventions are carried out in a company, some workstations may be considered at risk when one method is used, while they will not be deemed at risk if another method is used. The findings of this study show that it is possible to choose a method based on the desired result. These differences might be explained, in part, by the different variables (see Table 3.9) taken into account by the methods. For example, EN 1005-3 attempts to take into account the cumulative effect of repeated awkward postures and force applications on the musculoskeletal system, while other methods such as 3D SSPP do not. Mirka et al. (2006) also emphasize this phenomenon in their work.

3.5.4 Risk assessment and intervention

If the vast majority of workstations are considered at risk with one method, it can become difficult to prioritize interventions and know where to allocate resources. Jones et al. (2005), Marras et al. (1999) and Waters et al. (1993 and 1998) have shown in previous studies that a complete assessment should be done using more than one method. A given workstation may present risk factors that are not considered by some methods. Using more than one method can not only help prioritize interventions, it can also ensure that risk factors not taken into account by one of the methods get evaluated. Such an approach can, however, rapidly lead to unacceptably high costs for the practitioner.

The use of the QEC alone, for example, does not provide information on the maximum acceptable weight for a manual handling task (unlike Mital et al. 1997, for example). In the case of an intervention to make changes to a workstation, the QEC used alone offers little guidance, while the Mital et al. (1997) method provides an upper-limit value. The question of a given method's cost is also an important factor, since obtaining an overview of a department's situation by analyzing a number of workstations with biomechanical software such as 3D SSPP or 4D WATBAK requires much more time, for example, than using either the QEC and FIOH observational methods. During this study, for instance, an analysis using the QEC and Mital et al. (1997) methods required an average of 30 minutes, while ergonomists took about an hour to complete the 14 items assessed by the FIOH method or conduct an analysis using 3D SSPP. It is important to remember that for 3D SSPP, one to four postures per workstation were analyzed, so the time required to assess a single posture using this method could be estimated at about 20 minutes. Finally, 4D WATBAK and EN 1005-3 each took an average of 3 and 4 hours of work, respectively, since these methods require a time study. The EN 1005-3 standard also required that 3D SSPP be used to calculate the moment values and obtain the resultant moment and that the force distribution parameters be obtained for the population (i.e. by using software like 3D SSPP). The cost of using a method like EN 1005-3 therefore may become significant, which must be factored in when selecting a method.

If using more than one method, the sequence becomes important. For example, less stringent methods such as 3D SSPP and 4D WATBAK will likely provide little additional information useful for prioritizing interventions if they are used after the QEC method. On the other hand, a biomechanical calculation used in conjunction with the EN 1005-3 standard is a useful method combination that takes a larger number of variables into account.

Given the conflicting results recorded by some pairs of methods, it is important to use the same method during an intervention if one wants to compare the risk level before and after making changes to a workstation. Even if a given method is not conservative (e.g. 3D SSPP, 4D WATBAK), the comparison of raw data values before and after workstation changes would likely provide information useful in assessing the changes made. Therefore, the methods chosen could be a function of the desired goal: the assessment of a group of workstations in order to prioritize future company interventions (QEC, for example), or the collection of more detailed information to determine threshold values to make changes at a specific workstation (such as the data obtained with the Mital et al. (1997) guide and the EN 1005-3 standard).

The QEC and FIOH methods make use of the opinions of both the worker and the observer, a beneficial combination that enables the worker to answer questions about the workstation. Through these questions, valuable information can be acquired to guide the choice of changes to be made to the workstation, information that is not provided by other methods like Mital et al. (1997), 3D SSPP, 4D WATBAK and the EN 1005-3 standard. A method that does not include direct interaction with the worker (e.g. to get his/her assessment) may, for example, fail to explain why certain parts are more difficult to handle than others. If the part is difficult to handle because it is difficult to grasp and therefore requires greater effort, the FIOH and QEC methods will likely provide this information, which is crucial for implementing an ergonomic intervention at the workstation in question. A method that takes into account the opinion of more than one worker per workstation would thus be very useful. However, one must be careful when using worker's opinion since they are subjective and thus may be affected by a number of variables not necessarily related to the workstation exposures being assessed (i.e. misrepresentation, a worker who is in pain) (Balogh et al., 2004).

Both 3D SSPP and 4D WATBAK biomechanical modelling software provide quantitative information on the load at the worker’s back and other joints during each posture, the load being handled, and the force applied to an object. Variability in replicating the worker's posture can cause variations in the values of lumbar compression, shear and lumbar moment (Sullivan et al., 2002). When 3D SSPP is used alone, however, the analysis does not take handling frequency into account, unlike 4D WATBAK, which provides cumulative indices (e.g. LBP Index). The model is more effective at analyzing the slow or rare movements of a task involving heavy load handling, compared to other methods like the Mital et al. (1997) guide. The biomechanical calculation assumes that the effect of acceleration and momentum is negligible. Each workstation task deemed critical must be assessed. While a posture might be acceptable according to the model, it may not be in reality if it is done repeatedly or at speed. The method is therefore less suitable for a workstation where the worker has to frequently handle a light load or where one needs to assess the risk associated with a repeated application of force. In addition, the posture must be replicated on a digitized mannequin with a specific gender and body shape and size. If the biomechanical calculation is done for a man of medium height, for example, the assessment will not necessarily represent the real workstation risk level for a tall man or a small woman. The use of this method means the user must make a choice regarding the mannequin's anthropometric data. This is also true for 4D WATBAK, which on the other hand takes into account the duration and frequency of workstation postures. The 4D WATBAK analysis is much longer and therefore more costly to carry out because it requires a time-motion study in addition to the software analysis of each individual critical workstation postures. For this study, the 4D WATBAK analysis required 2.9 hours of work on average (the more varied the postures and the longer the cycle time, the longer the analysis). Furthermore, 4D WATBAK uses a 2D model, while 3D SSPP uses a 3D model (Chaffin et al., 2006). Some parameters of the force applied while doing the task may therefore not be taken into account by 4D WATBAK, which seems to be the case here, since 4D WATBAK failed to detect the posture differences between the tree nursery and appliances sectors. In both cases, 3D SSPP and 4D WATBAK do not take into account the nature of the object handled (i.e. instability of the load, poor grip on the load or interface with the ground). While the Mital et al. (1997) tables consider several factors that affect the maximum acceptable load (see Table 3.9) and take into account handling frequency, they are only applicable to workstations with manual handling tasks. If the worker is in a posture that restricts the back (e.g., standing for an entire shift with little movement or bending) without necessarily handling loads, the Mital et al. (1997) tables are not appropriate. The QEC method, on the other hand, considers such a risk factor in its analysis of low back risk.

Finally, the EN 1005-3 standard, like the Mital et al. (1997) tables, can provide a threshold value if the assessment is being done so that changes may be made to the workstation. It requires the distribution parameters for the maximum capacity of the reference population, which 3D SSPP can provide. Incorporating factors such as frequency, duration and execution speed into its calculation, the EN 1005-3 method has the best face validity of all the methods studied because it takes into account the largest number of variables (see Table 3.9). However, the weightings used for the various risk factors could be construed as problematic and the distinct weighting schemes can lead to more stringent assessments in some cases (El ahrache and Imbeau, 2009).

Table 3.9

Job variables taken into account by the six methods

Variables / Method	Posture	Weight/	Frequency	Duration	Execution speed	Rest	Environmental factors	Psychosocial factors	Anthropometric data/gender	Worker's opinion	Other*
QEC Back	x		x	x				x		x	
FIOH Back	x	x								x	
Mital et al. (1997)	x	x	x	x			x		x		x
3D SSPP	x	x							x		x
4D WATBAK	x	x	x	x					x		x
EN 1005-3	(x)	x	x	x	x	x			(x)		(x)

*Quality of the hand coupling, distance from the body, handling precision, height of lifting and height of deposit. (X) Refers to variables examined by 3D SSPP that are used to determine the F_{Br} value in EN 1005-3.

3.5.5 Limitations and future work

In any case, it is difficult to identify which method best assesses the true low back risk because there is no gold standard (Takala and al. 2010). Each method lacks sufficient epidemiological data. Given the current situation, it would be very useful to have such a standard to provide a basis for comparison each time a new method is published.

A baseline measurement of the real risk at a workstation could have been used to evaluate the accuracy of the various methods' risk assessments. While no consensus regarding the risk presented by a workstation emerged from the risk-factor assessment methods used here, estimating the real risk, in terms of the incidence rate of musculoskeletal injuries at each workstation studied, would require a tremendous effort, one well beyond the scope of this study (Jallon, 2011). While this might be perceived as a limitation of this study, in fact it is not, since the objective was to compare different methods to each other on a sample of workstations deemed to be at risk of causing MSDs ; in other words, workstations that definitely presented a significant risk level (complaints, accidents, workers' impressions or those of the company's Occupational Health and Safety [OHS] stakeholders).

Given the number of methods published in recent years, further studies should be undertaken, preferably with large samples of workstations in a variety of workplaces. It would also be of very interesting to be able to apply these methods to workplace situations involving a wider range of MSD risk levels (not just workstations of concern).

3.6 Conclusion

This study has compared 11 indices of six methods used to determine low back risk taken from the recent ergonomic literature. The risk categories chosen for comparison were selected based on recommendations taken from the ergonomics literature. The study's sample size and sector diversity characterize it as general in nature, covering a wide range of workplace situations and industrial settings. The findings show that some workstations are deemed acceptable, that is, presenting a low risk of injury to the back, while the same workstations are considered high risk when assessed by other methods. Identifying the workstations that a company should prioritize for intervention therefore depends on the choice of method. This study gives the practitioner a much better idea of what to expect when selecting one method over another to assess a workstation.

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CHAPITRE 4 : ARTICLE 2

COMPARING THE RESULTS OF EIGHT METHODS USED TO EVALUATE RISK FACTORS ASSOCIATED WITH MUSCULOSKELETAL DISORDERS

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4.1 Abstract

This paper presents a comparison between eight different methods for determining risk factors for work-related musculoskeletal disorders. The QEC, FIOH *Ergonomic Workplace Analysis*, ACGIH HAL, Job Stain Index (JSI), OCRA, the EN 1005-3 standard, RULA and REBA methods were all used to assess 224 workstations involving 567 tasks in various industrial sectors. The results are compared using three risk categories (low, moderate, high). Data were gathered using video and measurements taken at the workstations. A questionnaire was also administered to employees participating in the study. The findings reveal that the various methods differ in their analyses of the same workstation. The EN 1005-3 standard assessing risk to the shoulder was the most conservative, identifying over 86% of the workstations as high risk. The HAL classified 37% of the workstations as low-risk to the hand and wrist compared to JSI with 9%. Correlation was highest between RULA and REBA, and between JSI and HAL. The QEC method proved to be the less stringent in assessing overall risk, classifying 35% of the workstations as high risk compared to RULA with 76%.

Relevance to Industry

These results provide a better understanding of the differences between various risk assessment methods. This information should be particularly useful for practitioners when choosing a method for an ergonomic intervention in industry.

4.2 Introduction

Musculoskeletal disorders are currently among the most widespread occupational pathologies. These disorders are a significant problem for industrialized countries (Buckle and Devereaux, 2002 ; NRC/IM, 2001). Representing one-third of work injuries, they have significant economic and social consequences (Morse et al., 1998 ; Punnett and Wegman, 2004). Costly for employers due to reduced quality and productivity, they also overburden the health system (Badley et al., 1994). According to the World Health Organization, MSDs are the leading cause of workplace disability in developed countries (WHO, 2003). In the U.S., the Bureau of Labor Statistics reports that MSDs account for 29% of all lost-time workplace injuries. A Health Canada (2002) study ranked MSDs as the second most costly health condition behind cardiovascular disease, with cancer ranking third. MSDs also account for the highest morbidity costs of all diseases combined. Similar statistics have been observed in a majority of industrialized countries (Punnett and Wegman, 2004 ; Yelin, 2003).

The work-related musculoskeletal risk factors most often cited in the literature include repetition, vibration, awkward postures and applications of excessive force (Buckle and Devereaux, 2002 ; Magnusson and Pope, 1998 ; Punnett and Wegman, 2004 ; Silverstein et al., 1986, 1987) Based on compelling evidence, the research reports clear links between these risk factors and the prevalence of MSDs (Grieco et al., 1998 ; NRC/IM, 2001 ; Putz-Anderson et al. 1997 ; Stock, 1991). The literature also provides evidence concerning the contribution of psychosocial factors to the development of these injuries (Putz-Anderson et al., 1997). The body areas most often affected are the lower back, neck, shoulders, elbows, forearms, wrists and hands (Buckle and Devereaux, 2002 ; Rempel and Punnett., 1997).

The scientific literature shows that intervention to reduce exposure to MSD risk factors remains the best prevention strategy (Burdorf, 2010 ; NRC/IM, 2001 ; Silverstein and Clark, 2004). This means that MSD risk factors must be assessed at workstations. According to Burdorf and van der Beek (1999), methods for assessing exposure to MSD risk factors can be placed in three categories: subjective judgment (e.g., questionnaire and measurement scale), systematic observation and direct measurement.

While the literature shows direct measurement methods to be more accurate and reliable (Juul-Kristensen et al., 2001), such methods require a significant investment of resources. Observational methods are still those most commonly used by practitioners (Takala et al., 2010). They are easier to use, less costly and more flexible when it comes to collecting data in the field. The number of published methods has increased in recent years (David, 2005). The ergonomic literature contains a variety of methods used by practitioners and researchers (Alhonen et al., 1989 ; Buchholz et al., 1996 ; Burdorf, 2010 ; Colombini, 1998 ; David et al., 2008 ; Dempsey et al., 2005 ; Hignett and McAtamney, 2000 ; Karhu et al., 1977 ; Keyserling et al., 1993 ; Li and Buckle, 1999b ; McAtamney and Corlett, 1993 ; Moore and Garg, 1995 ; Occhipinti, 1998.).

Many of these tools were developed to assess MSD risk factor exposure so that workplaces could be responsible for MSD prevention (Cole et al., 2003). While ergonomics practitioners, occupational therapists, employers, union workers and health and safety authorities need information on the most effective intervention methods available for preventing MSDs, the literature still offers little applied research that has tested these methods in the field for comparison and lacks information on which methods are the best at preventing MSDs (Takala et al., 2010). Therefore, the first step for determining which method to choose is to test them in the field and compare their respective results (Denis et al., 2005).

Some studies present methods from the literature according to their various characteristics: type of method, risk factors taken into account, validity and reliability (David, 2005 ; Kilbom, 1994 ; Li and Buckle, 1999a ; Malchaire et al., 2001 ; Takala et al., 2010) ; however, few studies compare the findings of the methods. Many studies (Apostoli et al., 2004 ; Bao et al., 2006 ; Brown and Li, 2003 ; Drinkaus et al., 2003 ; Jones and Kumar, 2007 ; Jones and Kumar, 2010, Joseph et al., 2011 ; Kee and Karwowski, 2007 ; Sala et al., 2010 ; Spielholz et al., 2008) present results comparing two to five methods for assessing MSD risk. Kee and Karwowski (2007), compare the OWAS, REBA and RULA methods using data from a sample of 301 postures collected in various industrial sectors. Spielholz et al. (2008), in a study with 567 participants from two sectors (manufacturing and hospitals), compare the Job Strain Index and ACGIH Hand Activity Level. With the exception of these studies, comparisons are generally made using sample sizes that are small and/or from a single workplace (e.g., Jones and Kumar, 2010).

Using a large collection of data gathered in industry over a four-year period, this study compares the findings obtained using eight methods for assessing MSD risk factors primarily to the upper limbs: the Quick Exposure Check (QEC) ; (David et al., 2003, 2008 ; Li and Buckle, 1999b, 1999c) ; the FIOH *Ergonomic Workplace Analysis* ; (Alhonen et al., 1989) ; Rapid Upper Limb Assessment (RULA) ; (McAtamney and Corlett, 1993) ; Rapid Entire Body Assessment (REBA) ; (Hignett and McAtamney, 2000) ; the American Conference of Governmental Industrial Hygienists Hand Activity Level Threshold Limit Values (ACGIH HAL-TLV) ; (American Conference of Governmental Industrial Hygienists, 2002) ; the Job Strain

Index (JSI) ; (Moore and Garg, 1995) ; OCRA ; (Colombini, 1998 ; Occhipinti, 1998) and the EN 1005-3 standard (CEN 2002). The eight methods were chosen for their ease of use and accessibility. These recent methods are likely to be used by non-researchers with varying levels of ergonomics expertise. Furthermore, for this study, all the methods were applied to the sample of workstations as a practitioner would use them, and in accordance with the recommendations of the methods' authors.

This study has the advantage of having been done with a large sample of workstations and tasks in various workplaces using a group of methods that have never been compared with each other.

4.3 Method

4.3.1 Sample

Data was collected from a sample of 224 workstations involving 567 tasks located in 18 plants from various industrial sectors: one appliance manufacturer, four plastics and composites manufacturers, six public-sector tree nurseries, five food processing plants, one aerospace manufacturer and one manufacturer of musical instruments (see Table 4.1). Given the small number of workstations in the food, aerospace and musical instrument plants, these sectors are shown as a single group (Other) to simplify the presentation of the results. The workstations were chosen (a) because they were targeted by CSST (Québec's Workers' Compensation Board) inspectors as having a history of MSDs, (b) directly by the company itself following workers' complaints or (c) by the company as workstations at risk for causing MSDs that were also in need of changes to increase productivity. In all cases, workstations were judged to be causes of concern for MSDs. For this study, assessments were performed on workstations with cycle times ranging from 0.03 minutes to 18.75 hours (see Table 4.1).

As such, the methods were compared using a sample with a wide variety of cycle times. The tree nursery and appliances sector workstations had the shortest cycle times (average 1.1 and 0.8 min), while those from the aerospace and plastics/composites manufacturing sectors had the longest (average 90.7 to 450.0 min). Where workstations were used by more than one worker, measurements were taken for more than one worker. Since workstations in the tree nursery sector are seasonal, some workers occupied more than one workstation over the course of the data collection. They were therefore observed and questioned at more than one workstation.

Table 4.1
Number of workstations and average cycle time for each sector (min.)

Sector	Number of workstations	Avg.	SD	Min	Max
Aerospace*	2	450.0	0.0	450.0	450.0
Food*	13	9.9	22.7	0.03	62.1
Appliances	49	1.1	0.8	0.1	3.4
Musical instruments*	2	73.7	37.5	47.2	100.2
Nurseries	97	0.8	0.8	0.02	4.5
Plastics and composites	61	90.7	169.7	0.6	1125.0

* Sectors grouped under "Other" in this article.

4.3.2 Data collection

Measurements needed to complete the various risk-factor assessments for MSDs were taken for each workstation studied. These measurements included the weight of the loads handled, the magnitude and direction of forces applied (measured using a Chatillon DFIS 200 digital force gauge and/or Mettler PE 16 scale), working heights, significant distances or displacements and shift length. Finally, using the Video Event Analysis application (Chappe, 2006), a video recording was made at each workstation as part of a time-motion study. About ten work cycles were observed for the majority of workstations in the sample (i.e.

workstations with short cycle times). For workstations with very long cycle times, the most critical tasks of the cycle where observed. The time-motion studies provided work-cycle durations, task distribution and movement frequency for the workstations studied.

A questionnaire to collect information from workstation employee opinions, required for the QEC and FIOH assessment methods, was administered. The workers rated their upper extremity exertion on the Borg perceived exertion scale (Borg, 1998). This input is required by the OCRA, HAL and JSI methods. In cases with more than one worker at a workstation, more than one interview was conducted to collect the information. A total of 516 workers between the ages of 22 and 67 working at 224 workstations, were questioned for the study

Following data collection in the company, workstation assessments were conducted by graduate students with training in occupational ergonomics or ergonomists with experience in the eight methods under study. Analyses were performed using the workstation videos. When recording the video, the ergonomist ensured that the camera was well-positioned to record the worker's entire body. The postures selected for analysis were those identified by the ergonomists as the most restrictive at the workstation. One to four restrictive postures per workstation, depending on the variability of the work, were assessed using the RULA and REBA methods.

4.3.3 Risk-assessment methods

(1) QEC. The Quick Exposure Check (QEC) (David et al., 2003, 2008 ; Li and Buckle, 1999b, 1999c) is posture-based. Combining the observer's assessment with the worker's answers to closed questions, it allows MSD risk factors to the back, arms, neck and upper extremities at a workstation to be assessed. In addition to an overall score for the whole body (QEC General), this method provides a risk index for each targeted area (back, shoulder-arm, wrist-hand and neck). The assessment takes posture, movement frequency, effort and shift length into account as well as psychosocial risk factors and exposure to vibration.

(2) FIOH. The *Ergonomic Workplace Analysis* method, developed by the Finnish Institute of Occupational Health (FIOH) (Alhonen et al., 1989) provides a wide-ranging ergonomic analysis of 14 points: (1) workstation design, (2) physical workload, (3) lifting, (4) working posture and movements, (5) accident risk, (6) task content, (7) task restrictions, (8) personal contact and communication, (9) decision-making, (10) attention required, (11) repetitiveness, (12) lighting, (13) thermal environment and (14) noise. The observer (expert) assigns each item a grade on a scale of either four or five. Each level corresponds to a detailed condition described by the method (i.e., a score of 5 indicates a situation posing a risk to the worker's health, while a score of 1 indicates acceptable and safe conditions). The workers evaluate the same characteristics of the workstation on a scale of 1 to 4 (very good, good, poor and very poor). In this study, a total possible score out of 10 was established for each item by combining the worker's and the observer's assessments.

(3)JSI. The Job Strain Index (JSI) (Moore and Garg, 1995) quantifies exposure to MSD risk factors for the hands and wrists. It provides an index that takes into account the level of perceived exertion, duration of effort as a percentage of cycle time, number of efforts, hand and wrist posture, work speed and shift length. Measurements of duration and frequency were obtained from the time-motion study. The force required (perceived exertion) to do the job was assessed by the worker using a perceived exertion scale (Borg, 1998).

(4) HAL. The Hand Activity Level (HAL) threshold limit values method (American Conference of Governmental Industrial Hygienists, 2002) assesses the risk to the hands and wrists. The evaluation is based on the hand activity level which takes into account the repetition and duration of effort as well as the Normalized Peak Force (NPF), (the relative level of effort a person would exert to do the task). The worker's impression of the maximum effort required by the task was determined using a perceived exertion scale (Borg, 1998). The 5th percentile for female strength was used to calculate the average. The number of efforts per second and their duration as a percentage of cycle time were obtained from the time-motion study.

(5) OCRA. The OCRA index (Colombini, 1998 ; Occhipinti, 1998) is based on the ratio between Actual Technical Actions (ATA), obtained by analyzing the task, and Reference Technical Actions (RTA). The RTA value is obtained by taking into account the frequency and repetitiveness of movements, use of force, type of posture, recovery period distribution and additional factors such as vibration and localized tissue compression. The OCRA method provides two separate indices (shoulder and elbow/wrist/hand) for each of the right and left sides of the body.

(6) RULA. The Rapid Upper Limb Assessment method (RULA) (McAtamney and Corlett, 1993) provides an overall score that takes into account postural loading on the whole body with particular attention to the neck, trunk, shoulders, arms and wrists. The overall score also takes into account the time the posture is held, the force used and the repetitiveness of the movement.

(7) REBA. The Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000) method provides an overall score that takes all the body parts into account (trunk, legs, neck, shoulders, arms and wrists). The overall score takes into consideration the same additional factors as RULA as well as the quality of the hand-coupling.

(8) EN 1005-3. The European Standard, *Safety of machinery - Human physical performance - Part 3*: *Recommended force limits for machinery operation* (CEN, 2002) is a general-purpose method that helps designers assess the risk related to force application during work. The acceptable force is obtained by applying various multipliers, i.e., speed, duration and frequency of actions, to a basic capability, which is represented by the maximum capability of the 15th percentile worker. The 3D SSPP software (version 5 and 6) from the University of Michigan Center for Ergonomics (2001) was used to obtain the population capability distribution parameters that in turn were used to obtain the basic value for the shoulder (i.e., the 15th percentile maximum moment for the target worker population ; see EN 1005-3). The reduced value was obtained by following the calculation steps using the standard's proposed coefficients.

4.3.4 Method comparison criteria

To allow comparisons of the methods, which do not use the same type of index, each method's results were categorized according to three risk levels, using the threshold values described in Table 4.2. The risk categories were established from recommendations made in the literature. They allow risk to be assessed based on a practitioner's discretion in identifying action categories when deciding whether or not to prioritize the intervention. The highest risk category indicates a priority need for ergonomic intervention. The moderate category describes a situation in need of further investigation before a decision is made on whether changes to the workstation are needed. The "low" risk category indicates an acceptable work situation, where the risk of developing an MSD is small.

Table 4.2

Risk categories used to compare results of the eight methods for assessing MSD risk

Methods	Low	Moderate	High
QEC General	< 40%	≥ 40%, <70%	≥ 70%
QEC Shoulder/arm	10 - 20	21 - 30	31 - 56
QEC Hand/wrist	10 - 20	21 - 30	31 - 46
FIOH MSD	< 2	≥ 2, < 6	6 - 10
RULA	1 - 2	3 - 6	7
REBA	1	2 - 7	8 - 15
JSI	0 - 3	3.1 - 7.0	≥ 7.1
HAL	< 0.56	≥ 0.56, < 0.78	≥ 0.78
OCRA Shoulder	≤ 1	≥ 1.1, ≤ 3.9	≥ 4
OCRA Hand/wrist/elbow	≤ 1	≥ 1.1, ≤ 3.9	≥ 4
EN 1005-3 Shoulder	≤ 0.5	> 0.5, ≤ 0.7	> 0.7

(1) QEC. The QEC General index combines the indices for all parts of the body (back, shoulder/arm, hand/wrist, neck). The percentage score is calculated by dividing the overall assessment score by the maximum overall score (X/X_{max}). The authors of this general index propose four categories of risk (Brown and Li, 2003). To allow comparisons with other methods, action levels 2 and 3 were combined to form one category (moderate). The “high" and "very high" risk categories proposed by the authors (David et al., 2008) for the QEC Hand/wrist and QEC Shoulder/arm indices were combined into a single "high" category, creating three risk categories. When more than one worker could evaluate a given workstation, the assessments were averaged to provide a single index for each workstation.

(2)FIOH MSD. For comparison between methods, scores 1, 3, 4 and 10, which are more closely related to MSD risk factors, were consolidated into a single FIOH MSD score. To allow comparisons with the other methods which only use three, risk categories 3 and 4 were combined into a single category. The worker's assessment and that of the observer, were combined to provide an average score out of 10 for items 1, 3, 4, and 10. The final FIOH MSD score was determined by calculating the average of these four scores. When more than one worker could evaluate a given workstation, the assessments were averaged to provide a single index for each workstation for each MSD item.

(3) JSI. The authors propose four risk categories for interpreting JSI results. To allow comparison between methods, the four categories were reclassified into three after Jones and Kumar (2010). The two intermediate categories were regrouped under the single "moderate" heading. The method provides an assessment for both sides of the body ; the highest score was selected for the inter-method comparisons. When more than one worker assessed the workstation, the average perceived exertion was used for the analysis.

(4) HAL. This method has three risk levels. The risk level is determined by the Normalized Peak Force (NPF)/HAL ratio. A ratio lower than the Action Limit (AL) corresponds to an acceptable risk, whereas a score exceeding the Threshold Limit Value (TLV) is interpreted as a non-acceptable risk. As with the JSI, the highest score (form left and right) was used for the analyses. When more than one worker assessed the workstation, the average perceived exertion was used for the analysis.

(5) OCRA. For this method, which has four risk assessment categories, the two intermediate categories were combined to form a single "moderate" category. The highest from the left and right scores was used in the analyses. When more than one worker assessed the workstation, as for the HAL and JSI methods, the average perceived exertion was used for the analysis.

(6) RULA. This method's four risk levels were consolidated into three by regrouping the two intermediate categories into one "moderate" category (Jones and Kumar, 2010). At workstations with more than one task, a RULA analysis was performed for each task. The most difficult task (i.e., that with the highest score) was used for the comparisons between methods.

(7) REBA. For this method, which provides a five-level assessment, the "low risk" and "medium risk" were combined into a single "moderate" category while "high risk" and "very high risk" were merged to form a single category (Jones and Kumar, 2010). A REBA analysis was performed on the same tasks evaluated by the RULA method. For each task, the left and right sides of the body were assessed. The highest score was used when making comparisons with all the other methods except RULA ; in this case, each individual task that was assessed by the two methods was compared.

(8) EN 1005-3. As specified in the standard, the exposure index was calculated to protect 85% of the female population. The 15th percentile value of the distribution of the maximum moment to the shoulders in the most-used plane of motion for a female population (i.e., the one with the lowest able population percentage according to the 3D SSPP software's strength report) was used as the basic force for calculating the reduced capacity in accordance with the standard. If the ratio of the value of resulting moment to the shoulder and the reduced capacity calculated using the standard was higher than 0.5, the task was considered to present a moderate risk. The risk was considered high when this ratio was greater than 0.7 (EN, 2002). In the case of workstations with more than one task, the task with the highest risk using this ratio was the one used for comparisons between methods.

Table 4.3 shows the number of tasks and workstations assessed using each method. The number of tasks may differ from the number of workstations evaluated, since some methods allowed several tasks per workstation to be assessed (e.g., RULA, REBA, EN 1005-3). In the case of methods where the number of workstations is less than 224 (the total number of workstations included in the study), some information was either missing or unusable. For example, when it came to the HAL, JSI and OCRA methods, if the worker’s perceived exertion rating could not be collected, this method could not be applied to the workstation, resulting in a sample size of less than 224. For the EN 1005-3 standard, the number of workstations analyzed corresponds to those among the 224 for which the shoulder was the area under most strain, according to the percent capable from the 3D SSPP strength report (the back was the region under most strain in 40% of the postures analyzed ; hips, elbows or wrists in 31% of cases). This was done so that a practitioner could prioritize the analysis of the body region considered to be under the most strain, rather than analyzing numerous body areas.

Table 4.3

Total number of workstations and tasks evaluated using the eight methods

Methods	No. of workstations	No. of tasks
QEC General	217	_
QEC Hand/wrist index	217	_
QEC Shoulder/arm index	217	_
FIOH MSD	220	_
RULA	224	566
REBA	224	567
HAL	195	_
JSI	195	_
OCRA Shoulder index	204	_
OCRA Hand/wrist/elbow index	204	_
EN 1005-3 Shoulder	117	166
Total	224	567

4.3.5 Data analysis

JMP statistical software for Windows (SAS Institute Inc. version 9.0.2) was used for the data analysis, which included descriptive statistics, the Tukey-Kramer HSD test, Pearson's intercorrelations and two-by-two contingency tables.

To compare averages between sectors, the Tukey-Kramer HSD parametric test was selected because of the large number of observations and the equal variance of the distributions (homoscedasticity). The Tukey-Kramer HSD method is conservative when sample sizes are unequal. The Bonferroni criterion was applied to control the risk of alpha inflation, given the multiple comparisons. Results showing values above the significance threshold ($p<0.05$) were considered statistically insignificant. P-values between the significance thresholds $p <0.05$ and the threshold value determined by the Bonferroni criterion ($p<0.05/k$ where k = no. of pairs compared) identified comparison pairs with a high likelihood of statistical significance in the absence of multiple comparisons (i.e., protection against alpha error inflation). Correlation-coefficients (Pearson's) helped identify the degree of association between two compared methods.

For the OCRA method, correlation coefficients and comparisons of averages between sectors were calculated using only the values located below the 90th percentile of the distribution of scores (see Table 4.6). However, removal of extreme values did not affect the calculation of discrepancy scores between methods.

4.4 Results

4.4.1 Risk classification

Figure 1 illustrates the risk level distribution for all the workstations in each method's sample. At first glance, a high majority of workstations emerge as moderate or high risk. The QEC General index assessed the smallest proportion of workstations as high risk (35%) followed by FIOH MSD with 42%. The FIOH MSD, RULA and REBA methods did not identify any workstations as low risk. REBA and RULA classified the majority of workstations (70% and 76%, respectively) in the high risk category. In categorizing 37% of workstations as low-risk, HAL emerged as the least conservative method for assessing risk to the hands and wrists, followed by the OCRA Hand/wrist/elbow and JSI indices, which ranked only 22% and 9%, respectively, in this category. The QEC Hand/wrist index is even more stringent, classifying only 65% of workstations in the high-risk category. The EN 1005-3 standard classified the most workstations as posing high risk to the shoulder (86%). The QEC Shoulder/arm and OCRA Shoulder indices divided the workstations similarly, assessing 70% and 69%, respectively, as high risk.

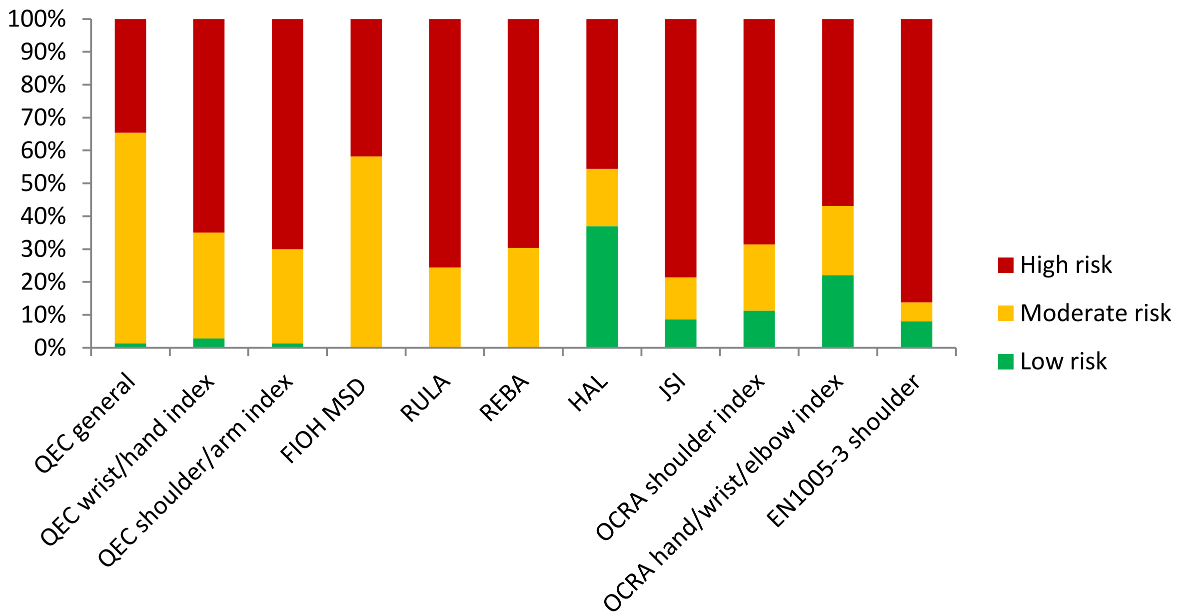

Figure 4.1 Distribution of risk levels for all workstations based on results of the 11 indices obtained from the eight assessment methods

4.4.2 Agreement and intercorrelation between methods

The creation of two-by-two contingency tables shows paired comparisons of the risk levels obtained using each of the eight methods (see Table 4.4). The values in the first column show the discrepancy percentage for one risk category per pair of methods. The second column shows the discrepancy percentage for two risk categories. The third column shows the mean discrepancy score for the two paired methods. This score is calculated by combining the discrepancy score for one risk category with the discrepancy score for two risk categories multiplied by two. No pair of methods is in complete agreement.

The pairs of methods that provided more general assessments of the workstations (QEC General, FIOH MSD, RULA and REBA) had average discrepancy scores lower than those of the methods that assessed the risk to a specific area (e.g., shoulder/arm or hand/wrist). On average, the correlations were also stronger and more significant ($p<0.0001$). Of the methods assessing risk to the hands and wrists, the QEC Hand/wrist and the HAL indices were most at odds, with the highest discrepancy score (90.14) and the weakest correlation. The QEC Hand/wrist estimates the risk as higher by one or two risk categories in 65% of cases when compared to HAL. The strongest and most significant correlations ($p<0.0001$) that emerged were between RULA and REBA (0.67) and between HAL and JSI (0.69). When assessing risk to the shoulders, the QEC Shoulder/arm and the EN 1005-3 standard, were closest in their conclusions regarding risk categories (33.71).

Table 4.4

Paired comparisons of risk levels obtained using each of the eight methods and pairwise correlations

Paired methods	Percentage of discrepancy for one risk level	Percentage of discrepancy for two risk levels	Mean discrepancy score	Paired correlation coefficient
RULA/REBA (N=543)	26.3	0	26.3	0.67***
RULA/QEC General (N=214)	42.5	0.5	43.5	0.37***
RULA/FIOH MSD (N=217)	41.9	0	41.9	0.28***
REBA/QEC General (N=214)	41.1	0	41.1	0.35***
REBA/FIOH MSD (N=217)	41.5	0	41.5	0.37***
QEC General/FIOH MSD (N=216)	38.4	0	38.4	0.28***
QEC Hand-wrist/HAL (N=193)	39.4	25.4	**90.1**	0.01
QEC Hand-wrist/JSI (N=196)	37.9	6.6	**51.0**	0.17**
QEC Hand-wrist/OCRA Hand-wrist-elbow (N=201)	38.8	12.0	**62.7**	0.03
QEC Shoulder-arm/OCRA Shoulder (N=201)	33.8	8.5	**50.8**	0.12
QEC Shoulder-arm/EN1005-3 (N = 86)	19.8	7.0	33.7	0.18
HAL/JSI (N=195)	28.2	18.5	**65.1**	0.69***
OCRA Hand-wrist-elbow/JSI (N=196)	26.2	13.7	**53.6**	0.32***
OCRA Hand-wrist-elbow/HAL (N=195)	29.7	24.6	**79.0**	0.16*
OCRA Shoulder/EN 1005-3 (N=81)	23.5	12.4	48.2	0.19

In bold: discrepancy score > 50

Significance thresholds: *p < 0.05 **p < 0.01 ***p < 0.0001

4.4.3 Comparison of averages between sectors

Table 4.5 presents the results of the Tukey-Kramer HSD test, used to determine which pairs of sectors had different average results from the eight methods. Any p-values below the threshold adjusted for Bonferroni are listed in bold and indicated by two asterisks (**), while any p-values located between the significance thresholds $0.05>p>0.0083$ are identified by one asterisk (*). The findings show statistically significant differences between certain sector pairs. The tree nursery industry emerges as the one whose averages most often differ from those in other sectors. Among other things, the findings show statistically significant differences in the averages obtained with the FIOH MSD and REBA methods.

Table 4.5

P-values of Tukey-Kramer test to compare sectors and risk output scores

	QEC General	QEC Hand/wrist index	QEC Shoulder/arm index	FIOH MSD	RULA	REBA	HAL	JSI	OCRA Shoulder index	OCRA Hand/wrist/elbow index	EN 1005-3
Tree nursery/Appliances	0.454	0.235	0.996	0.999	0.375	**0.000****	0.994	0.008*	0.694	0.805	0.288
Tree nursery/Other	0.053	0.013*	0.247	**0.000****	0.484	**0.000****	0.411	0.986	0.766	0.916	0.271
Tree nursery/Plastics-composites	0.895	0.876	0.417	**0.000****	0.129	**0.000****	0.065	0.924	0.992	0.71	0.229
Plastics-composites/Appliances	0.205	0.685	0.692	**0.000****	0.982	0.993	0.138	0.003*	0.872	0.1	0.943
Plastics-composites/Other	0.022*	0.063	0.036*	0.998	0.1	0.349	1.0	1.0	0.663	0.552	0.967
Other/Appliances	0.447	0.345	0.239	**0.000****	0.989	0.491	0.438	0.097	0.353	0.618	0.999

* P-values between 0.05 and 0.05/6 = 0.0083
****** (in bold) significant p-values (Bonferroni criterion applied

4.4.4 High risk level agreement

Table 4.6 shows the percentage of agreement, solely with regard to the workstations assessed as high risk by one method. All workstations identified as high risk by FIOH MSD were also identified as such by RULA in 89% of the time. Of the workstations identified by the QEC General index as high risk, RULA and REBA agreed with the assessment 96% and 91 % of the time respectively. Conversely, when it came to the workstations identified as high risk by RULA and REBA, the QEC General only agreed on 45% and 46% of them.

Table 4.6

Percentage of agreement on priority per pair of methods

	QEC General	FIOH MSD	RULA	REBA	QEC Hand/wrist index	OCRA Hand/wrist/elbow index	HAL	JSI	QEC Arm/shoulder index	OCRA Shoulder index	EN 1005-3
QEC General N= 75		56%	96%	91%							
FIOH MSD N=90	47%		89%	82%							
RULA N=160	45%	50%		82%							
REBA N=147	46%	50%	89%								
QEC Hand/wrist index N= 130						64%	46%	81%			
OCRA Hand/wrist/elbow index N=112					74%		56%	91%			
HAL N=88					68%	72%		97%			
JSI N=152					89%	67%	56%				
QEC Arm/shoulder index N=60										73%	93%
OCRA Shoulder index N=54									82%		93%
EN 1005-3 N=72									78%	69%	

4.4.5 Exposure index

Table 4.7 shows the average exposure index for the results obtained from the OCRA and EN 1005-3 methods. An exposure index of 1.0 indicates a safe exposure level (e.g., the number of activities performed at the workstation is within the number recommended by OCRA). An index higher than 1.0 indicates that the risk factor exposure is higher than recommended. The results show the distribution range for these two methods, which have no fixed measurement scales (unlike, for example, QEC and RULA).

Table 4.7

Average exposure indices for the OCRA and EN 1005-3 methods

	Avg.	SD	Min.	Max.
OCRA Shoulder index	118.5	411.7	0.1	4320
OCRA Hand/wrist/elbow index	61.1	213.7	0.1	1800
EN 1005-3	8.4	12.6	0.3	86.1

4.5 Discussion

4.5.1 Risk assessment and agreement between methods

The objective of this study was to compare various methods to each other using a set of workstations sample that definitely incorporated a significant risk level. On the whole, more than half of the methods identified a majority of workstations as moderate or high risk. The results show that no pair from among the eight methods was in complete agreement. The MSD risk assessment with the 11 indices produced mixed results. The EN 1005-3 standard seems to be the most stringent method for assessing risk to the shoulder

(86%), while the QEC General is the least strict of the general indices, ranking only one third of the workstations as high risk.

The EN 1005-3 result can be partly explained by the fact that only those workstations for which the shoulder was the area under most strain were analyzed. Had all workstations been analyzed, it seems plausible that the risk-category distribution would have been different. Although, considering that the standard is fairly stringent the risk-category distribution may not have been that different.

The FIOH MSD and QEC General methods are in agreement about 60% of the time when all workstation risk categories are combined (Table 4.4). Regarding high-risk positions (Table 4.6), however, these two methods agree in just 56% and 47% of cases, respectively. A workstation assessment conducted with the QEC would not signal the same priorities as an assessment with FIOH MSD. Given the similarities between these methods (both incorporate the opinions of a qualified observer and the worker), a higher level of agreement might be expected. The picture is different for FIOH MSD and RULA. The workstations assessed as high risk by FIOH MSD were nearly all identified as such by RULA as well ; however, of the workstations determined by RULA to be at high risk, only 50% were assessed as such by FIOH MSD. The RULA method would thus seem preferable to the FIOH MSD if a more conservative approach is desired.

RULA and REBA did not identify any workstations as low risk. Both methods found 100% of the workstations to be moderate to high risk. Nothing indicates that one method assesses risk as higher when compared to the other. The comparison results for RULA and REBA show closer agreement than that obtained by Kee and Karwowski, (2007). Those authors reported 48% consistency, as compared to 73.7% in our study. The variation can be explained by the differences between the action levels and risk categories used. Using the same risk categories as this study, Jones and Kumar (2010) generated 66% agreement between RULA and REBA, albeit with a very small sample (four workstations in the same industrial sector).

Of the methods assessing risk to the hands and wrists, JSI is the most severe (79%). With 36% of workstations classified as low risk, HAL is the least conservative of this group of methods. With a correlation coefficient of 0.69 ($p < 0.001$), the results of this study are comparable to those described in the literature for comparisons between JSI and HAL (Apostoli et al., 2004 ; Bao et al., 2006 ; Jones and Kumar, 2007 ; Spielholz et al., 2008). Given that JSI identified 96.6% of the same workstations considered high risk by HAL, JSI could be chosen over HAL if a more conservative approach is desired (Table 4.6).

The QEC Hand/wrist and OCRA Hand/wrist/elbow indices show similar results for the number of workstations classified as high risk, but do not classify the same workstations in this category. OCRA and QEC are in agreement 57% of the time for all risk categories combined. There is a 20% difference in the percentage of workstations classified as low risk. When it comes to high-risk workstations, the QEC Hand/wrist identifies 74% of those identified by the OCRA Hand/wrist/elbow. In light of the considerable effort the OCRA method requires, as compared to the QEC (Aubry, 2006), the hurried practitioner may wish to choose the QEC, given the high level of agreement between the two methods in identifying high-risk situations.

4.5.2 Differences between sectors

The FIOH MSD and REBA methods are those that discriminate between industrial sectors. The REBA method appears to be the only method able to capture the very awkward postures that were regularly observed only in the tree nursery sector (squatting, sitting on the ground, lumbar flexion greater than 90° and torso twisting). As for FIOH MSD, the differences between Tree nursery/Other and Tree nursery/Plastics-composites show the ability of this method, like REBA, to detect the more extreme postures adopted in nurseries. The tree nursery sector's much shorter cycle times compared to two other sectors (Plastics-composites and Other) also influenced the FIOH MSD score that assesses repetitiveness. The differences between Plastics-composites/Appliances and Other/Appliances also emerge in the score assessing repetitiveness since cycle times are shorter at Appliances sector workstations than they are at workstations in the Other and Plastics-composites sectors. Another difference between Plastics-composites and Appliances occurs in the FIOH score assessing lifting. The loads handled were heavier in the Plastics-composites sector than in Appliances, where the work involved handling light loads at a high rate of repetition (Chiasson et al. 2011).

4.5.3 Differences between methods and intervention

If the vast majority of workstations are considered at risk with one method, it can become difficult to prioritize interventions and to know where to allocate resources. Jones et al., (2005), Marras et al., (1999), and Waters et al., (1993 and 1998) have shown in previous studies that a complete assessment should be done using more than one method. A workstation can have risk factors that are not considered by some methods (see Table 4.9). The choice of method should be made according to the goal of the intervention (e.g., to prioritize interventions or to provide a target design value). Using more than one method can not only help prioritize interventions, it can also ensure that risk factors not taken into account by any one of the methods are assessed. The use of more than one method can, however, rapidly lead to unacceptably high costs for the practitioner. During this study, for instance, the QEC, HAL, REBA and RULA methods required the same amount of effort in terms of the data analysis (27 min ± 16.2). Assessing the 14 FIOH points required a little less than an hour of the ergonomists' time (53 min ± 29.5). The OCRA method (Shoulder and Hand/wrist/elbow) required 70 minutes of analysis (± 28.9) as compared to the JSI, which took one quarter of the time (16 min ± 6.49). The HAL, JSI and OCRA methods also required a time study to provide movement duration and frequency. The time study required nearly 3 hours, on average, for each workstation (170 min ± 92.19). In particular, workstations with long cycle times contributed to prolonging the analysis for these methods.

When the worker's perception is taken into account in the workstation assessment (e.g., QEC, FIOH, HAL, JSI and OCRA), the risk assessment may be biased. Mital et al., (1993) noted that more experienced subjects tend to underestimate the effort exerted as compared to less experienced subjects, when effort is measured using a Borg scale. The questions that workers answer in the QEC and FIOH methods are, nonetheless, a very useful source of information for understanding the root causes of the most severe risk factors and the workstation tasks that are most difficult for the worker. However, when the goal of an intervention is to make changes to a workstation, the QEC or FIOH used alone provide little guidance regarding the targets to be met, while the EN 1005-3 standard provides an upper-limit value. An important aspect of MSD prevention (Malchaire, 2001) is choosing a combination of methods that provides both detailed information from the worker and a design target.

The question of the cost of using a method is also an important factor since for example, analyzing a number of workstations to get an overall picture of the situation in a department using a method such as OCRA or EN 1005-3 that requires a time study in addition to posture analysis using biomechanical software (e.g. 3D SSPP) becomes too costly for assessing all of a company's workstations. The learning curve for the OCRA method is significantly steeper than those for the other methods examined in this study (Malchaire, 2001). In contrast, the QEC and FIOH methods can be used quickly to conduct an initial screening of the workstations thought to be most at risk in a large sample (Chiasson et al., 2011). In addition, these methods have the advantage of providing sub-scores (e.g., the QEC Hand/wrist index) for analyzing different parts of the body separately if the overall result appears to be moderate, for example. It would also be interesting to be able to generate an index for each area of the body from a RULA or REBA analysis.

While no single method seems to stand out, the EN 1005-3 standard and OCRA methods take into account the greatest number of variables (Chiasson et al., 2011). As shown in Table 4.7, however, the OCRA method's score distribution is problematic. The results obtained with certain workstation conditions can lead to extreme scores. With the OCRA method, when a worker assigns a score of 5 or higher on the Borg scale to an element of the task with a duration greater than 10% of the overall time, the force factor to be applied is 0.01, which has the effect of significantly increasing the OCRA index (Aubry, 2006). This factor is thus highly detrimental and has a tremendous impact on the final score.

As Li and Buckle (1999a) mention, an additional problem linked to the use of certain methods is that they have often been developed within a specific research context. For this reason, they can sometimes be unreliable when applied in a different context. This is true of RULA, which would adapt poorly to a highly varied work situation.

JSI and HAL are more appropriate for assessing workstations with short cycle times. However, Bao et al., (2006) report that the differences between JSI and HAL in defining repetitive exertion might lead to measuring different physical exposure phenomena and produce different results.

REBA and RULA pose a problem when choosing the posture that should be assessed at the workstation. If a workstation has several tasks, then how should all the RULA results for each task's most critical posture be combined?

Finally, it should also be mentioned that sometimes there are limitations to observing the posture of various parts of the body. Assessing risk to the hands and wrists using a method that takes posture into account can be difficult. Genaidy et al., (1993) and Baluyut et al., (1995) found that the accuracy of posture observation varied with the size of the body part ; the bigger the area, the more accurate the estimate. Juul-Kristensen et al., 2001) carried out the posture assessment using an observation-based method and concluded that reducing the number of classification categories (broader categories) reduced the risk of a classification error. Lowe (2004) also draws this conclusion, mentioning the need to compromise between getting the right measurement and the precision of the measurement scale, which can help guide the choice of method. This is the case for JSI, which offers five posture categories, as opposed to the QEC Hand/wrist, which offers two. The more precise posture categories in the JSI method add little value if they cannot be properly assessed by the observer. On the other hand, the two QEC Hand/wrist posture categories may be sufficient to identify the workstations that are intervention priorities within a large-scale prevention strategy. In this study, the QEC Hand/wrist also flagged 89% of the at-risk workstations assessed by JSI. In short, while quantifying the exact posture is difficult, since it is not the only variable the method takes into account, the result remains useful for assessing workstation risk.

Since the results of this study suggest that there are differences between the methods and that it remains difficult to identify the best method for estimating the true MSD risk (Takala et al., 2010), selecting a method requires the user to have a good knowledge of the variables taken into account and an understanding of how they influence risk assessment (see table 4.9).

Table 4.8

Job variables taken into account by the eight methods

Variables Methods	Posture	Weight/effort	Frequency	Duration	Movements	Execution speed	Rest	Environmental factors	Psychosocial factors	Anthropometric data/gender	Worker's perception/Opinion	Other*
QEC	**x**	**x**	**x**	**x**	**x**				**x**		**x**	**x**
FIOH	**x**	**x**						(**Y**)			**x**	**x**
RULA	**x**	**x**	**x**									
REBA	**x**	**x**										**x**
JSI	**x**	**x**	**x**	**x**		**x**					**x**	**x**
HAL		**x**			**x**	**x**	**x**					
OCRA	**x**	**x**	**x**	**x**			**x**					**x**
EN 1005-3	(x)	**x**	**x**	**x**		**x**	**x**			(x)		(x)

* Visual accuracy, quality of the hand coupling, height of lifting, tissue compression, vibration
(**Y**) Variables considered by the method but not included in this study.
(x) Variables supported by 3D SSPP, used to determine the F_{Br} value in the EN1005-3 standard.

4.6 Conclusion and future work

This study compares 11 indices from eight methods for assessing MSD risk factors, primarily for the upper limbs, using the risk categories for these methods proposed in the literature. A large sample of 224 workstations involving 567 tasks in various industrial sectors was used to test the methods in a wide range of workplace situations and industrial contexts. The findings show that no two methods are in perfect agreement. Though it does not identify the method that best predicts MSD risk, this study does give the practitioner a much better idea of what to expect when choosing one method over another to assess a workstation. Given the number of methods published in recent years, further studies should be undertaken, preferably with large samples of workstations in a variety of workplaces, involving a wider range of MSD risk levels (not just workstations of concern). Finally, the methods compared in this study could be analyzed in greater detail to determine the influence or impact of each variable taken into account when calculating the risk level. This information could be very useful for developing new or modified MSD risk assessment methods.

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CHAPITRE 5 : ARTICLE 3

INFLUENCE OF MUSCULOSKELETAL PAIN ON WORKERS' ASSESSMENT OF EXPOSURE TO MSD RISK-FACTORS

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5.1 Abstract

This study compares the ergonomic risk-factor assessments of workers with and without musculoskeletal pain. A questionnaire on the musculoskeletal pain experienced in various body regions during the 12 months and seven days prior to the data collection was administered to 473 workers from three industrial sectors. The *Ergonomic Workplace Analysis* method, developed by the Finnish Institute of Occupational Health (FIOH), was then used by the workers and an ergonomics expert to assess the workstations. The ergonomic quality of the workstations and the need for change were also assessed by the expert and the workers at the workstation, using a visual analogue scale (VAS). The findings show that the workers in this study were exposed to significant musculoskeletal disorder (MSD) risk factors, according to the FIOH assessment and the high percentages of reported pain. The results also show that those who reported pain in the seven days prior to the assessment evaluated their workstations more negatively than subjects who reported no pain, while the expert found no difference between the workstations of the two groups.

5.2 Introduction

The prevalence of musculoskeletal disorders (MSDs) in workplaces is a major problem (NRC/IM, 2001 ; Stock et al., 2011). Several studies have been conducted to assess exposure to ergonomic risk factors in worker populations. For extensive surveys, worker self-report questionnaires are used to estimate the worker's exposure to a variety of risk factors (Burdorf and van der Beek 1999). Self-assessment can also be used by ergonomics practitioners when implementing an ergonomic intervention project in a company. Measuring exposure to risk factors is an important MSD prevention tool for both epidemiologists and ergonomists.

Some studies have examined the factors influencing the reliability and validity of workers' self-reports and self-assessments (Stock et al. 2005). Some of them have focused specifically on the effect of musculoskeletal pain on the worker's assessment of physical workload (Leijon et al. 2002 ; Wiktorin et al. 1993 ; Viikari-Juntra et al. 1996). This question is becoming particularly important for epidemiological studies with large-sized samples as well as for ergonomics practitioners and merits attention when an employee's assessment is taken into account to determine the workstation risk level and establish intervention priorities.

The assessment of a workstation’s MSD risk factors usually relies on observational methods. Several methods from the ergonomics literature are available to researchers and practitioners (David, 2005 ; Li and Buckle, 1999). They have the advantage of being fast and inexpensive to implement (Viikari-Juntura et al., 1996). Some were developed with the intention of supporting industry-led MSD-prevention efforts (Cole et al., 2003). Among other things, they can help prioritize ergonomic interventions. Some of these methods combine the worker's and expert's assessments to determine the workstation’s MSD risk level. Given the significant presence of MSDs in the population, it is only natural to assume that these methods can be used to assess workstations where workers are experiencing MSD symptoms. Therefore, it is important to know whether the workers' perception may be influenced if they are experiencing pain when these methods are being used. So far, only a few studies have focused on this subject. Some researchers have observed that workers with MSDs and those who were in pain reported greater exposure to MSD risk factors (Balogh et al., 2004 ; Hansson et al., 2001 ; Leijon et al., 2002 ; Viikari-Juntura et al., 1996 ; Wiktorin et al., 1993). These studies compare the differences between the exposure ratings of workers with pain and those with no pain in relation to exposure variables such as manual handling activity, movement repetitiveness and the posture of specific body regions. According to the findings of Donders et al. (2007), workers suffering from illness or chronic pain responded more negatively to questions characterizing their work than those not suffering from illness or chronic pain. Since all the study subjects worked for the same company and at similar workstations, this study shows that a negative perception of the job was strongly related to chronic pain rather than actual poor working conditions. The studies published to date have revealed similar levels of exposure to MSD risk factors. Furthermore, since none of these studies used an observational method developed for ergonomics practitioners, it is not clear whether such methods used in the context of an ergonomics practice would produce the same results as those developed by researchers for a specific research project.

The goal of the present study is to determine whether a worker’s report of musculoskeletal pain during the prior 12 months or 7 days influences the worker's perception of his/her workstation's ergonomic risk factors, when assessed using an observational method developed for practitioners. This is the first study to use this type of method to examine the influence of reported pain on workers' perceptions.

5.3 Methods

5.3.1 Subjects

The characteristics of the 473 subjects participating in the study are described in Table 5.1. While the overall sample was 60% female, their representation at tree nursery sector workstations (69%) was higher than the 36% average working in the two other sectors. Workers were between 17 and 66 years of age and had between 0.02 and 42 years of seniority in the company.

Table 5.1

Main characteristics of the respondents (n=473)

	Appliances	Plastics/composites	Tree nursery
Number	45	53	375
Age (years)	41.2 ± 10.8 (24 - 62)	42.9 ± 10.7 (19 - 60)	46.6 ± 9.7 (17 - 66)
Weight (kg)	81.6 ± 16.4	79.1 ± 15.3	66.5 ± 12.9
Height (cm)	1.7 ± 0.1	1.7 ± 0.1	1.6 ± 0.1
BMI	27.3 ± 5	27.2 ± 4.3	24.6 ± 4.2
Length of employment (years)	10.4 ± 9.1 (1 - 37)	12.6 ± 10.4 (0.1 - 42)	16 ± 9.8 (0.02 - 34)

5.3.2. Measurements

The data collected for this study can be separated into three parts: self-assessment of ergonomic risk factors, expert assessment of ergonomic risk factors and perceived musculoskeletal pain.

The data were collected in one appliance assembly plant, four plastics and composites plants, and six public-sector tree nurseries. A total of 473 workers were interviewed at 182 workstations over a four-year period. In the tree nurseries, up to 22 workers could be working at similar workstations. All subjects were interviewed at their workstations. They were released for a period of about 45 minutes to respond to the pain questionnaire and conduct the ergonomic assessment of their workstation. While the workers were given a copy of the questionnaire, the expert asked the questions in the form of an interview, noting the worker's responses and providing clarification when necessary. Subjects participated in the study on a voluntary basis. The data for this study were collected by three experienced ergonomics practitioners and four graduate students with training and field experience in ergonomics, all of whom are referred to as "experts" for this study. The experts had no employment relationship with the companies that participated in this study.

The first part of the questionnaire established the subjects' general characteristics: age, sex, weight, height and length of employment.

The *Ergonomic Workplace Analysis* method developed by the Finnish Institute of Occupational Health (FIOH) (Alhonen et al., 1989), which includes both expert and worker opinions, was used to provide a systematic and comprehensive assessment of the workstations. The method covers 14 topics: (1) work site, (2) general physical activity, (3) lifting, (4) work postures and movements, (5) accident risk, (6) job content, (7) job constraints, (8) worker communication and personal contact, (9) decision making, (10) repetitiveness, (11) attentiveness, (12) lighting, (13) thermal environment and (14) noise. An expert and the workers provide an assessment of each topic.

With the FIOH method, the workers subjectively assessed each of the 14 points using a four-level rating scale: *very poor*, *poor*, *good*, *very good*. The expert assessed the workstations on the same 14 topics using a four or five level scale (in the FIOH some topics use a four-level scale while others use five). A score of five (or four for some topics), represents maximum risk for the worker on the topic being evaluated. For each workstation studied, the data collected not only provided the information needed to complete the 14-point FIOH assessment, but other useful information as well (e.g., weight of loads handled, magnitude and direction of forces applied to objects as measured by a digital force gauge, working heights, any significant distances or displacements, shift length, and light and noise levels). Finally, a video recording was made at each workstation and the Video Event Analysis software (Chappe, 2006) was used to conduct a time-motion study. About ten work cycles were observed at the workstations with short cycle times, i.e. the majority of workstations in the sample). For those with very long cycle times, at least the most critical task of the cycle were observed. For the purposes of this article, only the results from the FIOH points related to physical constraints or MSDs are presented (i.e. FIOH points 1, 2, 3, 4, and 10).

The workers' perceptions and the expert's assessment were then obtained by asking two questions:

(1) "What is your perception of the ergonomic quality of your workstation?"

(2) "What is your perception of the need for changes to your workstation?"

Workers had to put a mark on a visual analogue 10 points scale (VAS), indicating their assessment of the ergonomic quality of the workstation (scale anchors: very poor ergonomics to perfect ergonomics). The questions above were asked following the FIOH assessment and a discussion with the workers to determine whether or not they had an opinion on the workstation's overall design quality with regard to ergonomics. Through this discussion the term was defined and explained to the workers to make sure they understood what they needed to assess. The prior workstation evaluation with the FIOH helped them better understand the assessment to be done. Another VAS was used for the second question (scale anchors: no changes needed to changes truly necessary). The expert interacting with the workers had to answer the same two questions using the same scales to provide his/her overall assessment of the workstation.

Finally, the workers' musculoskeletal pain was assessed using two series of questions. Questions came from the Enquête sociale et de santé du Québec of 1998 (Daveluy et al., 2001), which was adapted from the Standardized Nordic Questionnaire (Kuorinka et al., 1987). A first set of questions pertained to pain experienced in 11 body regions (neck, shoulders, arms, elbows, forearms/wrists, upper back, lower back, hips/thighs, knees, calves and ankles/feet) during the 12 months preceding data collection ; a second set of questions related to pain felt in the same body areas in the seven days prior to data collection. For each body region, workers were asked whether they had experienced any pain that had interfered with their normal activity over the past 12 months: *no, never ; yes, sometimes ; yes, often ; yes, all the time*. In the case of musculoskeletal pain experienced during the past seven days, workers were also asked whether the pain was work-related. For the same 11 body regions, the answer was selected from the following possibilities: *no pain ; yes, entirely related to my work ; yes, partly related to my work ; I don't know if related to my work ; not related to my work.*

5.3.3 Data analysis

For this study, the answers regarding the presence of pain were assigned values: "*pain*" was assigned a value of 1 and "*no pain*," a value of 0. The answers were processed in two ways. In Case 1, if the respondent answered "*yes, often*" or "*yes, all the time*" for at least one body region, the response was categorized as "*pain*" (1), but when the subject answered "*no, never*" or "*yes, sometimes*" for all body regions, the response was categorized as "*no pain*" (0). In Case 2, it was only when the worker answered "*no, never*" for all body regions that the response was classified as "*no pain*" (0). If the respondent answered "*yes, sometimes*", "*yes, often*" or "*yes, all the time*" for at least one body region he/she was included in the "pain" category (1). As for the data on pain experienced in the past seven days, "*no pain*" (0) was associated with a "*no pain*" response, while any of the other four responses for at least one body region was classified as "*pain*" (1).

The influence of pain on the perception of ergonomic risk factors at the workstation was measured using three categories of reported pain: pain experienced in at least one body region in the seven days preceding the study and pain experienced in at least one body region " *often*" or "*all the time*" (Case 1) and "*sometimes*", " *often*" or "*all the time*" (Case 2) in the 12 months preceding the study. The expert's evaluation was compared with that of the workers for all workstations. One-way analysis of variance (ANOVA) was used to compare the relationship between the pain reported and the workstation assessments of both groups of workers (those with pain and those without) and the expert (Table 5.4).

The 4-level scale used for the workers' assessments and the 5 or 4-level scales used by the expert were presumed to be interval type, as were the two VAS assessments.

JMP statistical software for Windows (SAS Institute Inc. version 9.0.2) was used for the data analysis. The pain data reported by the study subjects were compared with the prevalence of musculoskeletal pain in the reference population of Quebec as a whole, using data from the Enquête sociale et de santé du Québec of 1998.

5.4 Results

5.4.1 Musculoskeletal pain

Of the 473 subjects who participated in the study, 469 completed the survey on the presence of musculoskeletal pain in the previous seven days. The responses of 461 subjects were collected regarding the 12-month period.

Table 5.2 compares the prevalence of musculoskeletal pain for the 12-month reference period. The prevalence of musculoskeletal pain felt " *often*" or "*all the time*" in at least one body region during the 12-month period was compared to that of the Quebec population as a whole (Daveluy et al., 2001). Workers in the three sectors reported significantly more upper-limb pain during the 12-month period than did the general Quebec population ($p < 0.05$). Workers in the appliances sector also reported significantly more back pain than the reference population.

Table 5.2

Comparison of musculoskeletal pain felt “*often*" or "*all the time*" over a 12-month period, by sector.

	Quebec population**	Appliances		Plastics/composites		Tree nursery	
	%	*n*	%	*n*	%	*n*	%
Neck	13.8	10	22.2	9	17.0	45	12.6
Upper back	13.7	12	26.7*	7	13.2	58	16.2
Lower back	24.7	18	40.0*	17	32.1	98	27.3
Upper limbs	20.6	30	66.7*	18	34.0*	95	27.3*
Lower limbs	18.0	11	24.4	14	26.4	72	20.5

* Significant difference compared to the general Quebec population in the threshold p < 0.05.

**Source: Institut de la statistique du Québec (Daveluy et al.) 2001. Collection la santé et le bien-être. Enquête sociale et de santé 1998. 2e édition. Gouvernement du Québec. 710 pages.

Table 5.3 shows the prevalence of pain experienced during a 7-day period and that experienced during a 12-month period for Case 1 and Case 2, by sector. Proportionally, the prevalence of pain experienced in at least one body region during the seven days preceding the study is similar for all three sectors. In terms of pain experienced in the 12 months preceding the study, workers in different sectors responded in varying proportions regarding pain experienced "*often*" and "*all the time*". Subjects from the tree nursery sector reported less pain experienced "*often*" and "*all the time*" over a 12-month period (48.7%) as compared to workers in the appliances and plastics/composites sectors, who reported pain 80.0% and 58.5% of the time, respectively. Case 2, which takes into account pain experienced during the past 12 months "*sometimes*," "*often*" and "*all the time*", shows higher numbers because it includes one additional pain category (i.e. "*sometimes*") as compared to Case 1. Smaller differences between the sectors in Case 2 indicate that proportionally more workers in the tree nursery sector reported experiencing pain "sometimes" in a 12-month period. In tree nurseries, 371 subjects responded to the questionnaire on pain within a 7-day period, while 363 completed the questionnaire on pain during a 12-month period. In the other two sectors, all subjects responded to the pain questionnaire for both periods under study.

Table 5.3

Percentage of workers who experienced musculoskeletal pain in at least one body region during a 7-day period and during a 12-month period, according to 2 cases, by sector

	7 days (n= 469)		12 months, Case 1 (n=461)		12 months, Case 2 (n=461)	
	N	*%*	*n*	*%*	*n*	*%*
Appliances (n= 45)	40	88.9	36	80.0	44	97.7
Plastics/composites (n= 53)	44	83.0	31	58.5	49	90.6
Tree nursery* (n= 371 ; 363)	314	84.6	177	48.7	331	91.2

12 months, Case 1: workers who reported pain "often" or "all the time" during a 12-month period
12 months, Case 2: workers who reported pain "sometimes," " often" or "all the time" during a 12-month period
*(n = number of workers who were questioned regarding pain experienced during a 7-day period ; number of workers who were questioned regarding pain experienced during a 12-month period).

5.4.2 Ergonomics assessment and pain

Table 5.4 compares the averages of the workers' and experts' assessments, according to the pain reported for the two periods. The first value in the table is the ANOVA F-ratio. Under the F-ratio, between brackets, the average scores expressed as a percentage of the scale (to ease comparisons between different scales) of both groups of workers (with no pain and with pain) are shown. A positive sign (+) indicates a higher score assigned by workers suffering from pain.

The analysis of the scores for the five FIOH points, the score regarding the need for changes to the workstation and that related to the ergonomic quality of the workstation show significant differences between the two groups completing the pain report. Workers who reported pain in the seven days preceding the evaluation of their workstation assessed each of the five FIOH points significantly more severely ($p < 0.05$) although the expert’s workstation assessment indicated no difference between the two groups. For example, workers who reported pain in the prior seven days assessed work site (FIOH 1) less favorably than did their colleagues who reported no pain. For the same topic, the expert's evaluation showed no difference between the two groups. The averages for workers who had reported pain “*often*" or "*all the time*" over a 12-month period differed significantly from those of workers with no pain and not significantly from the expert's for FIOH points 1, 2, and 3. In the case of workstations occupied by workers who had reported pain in one area of the body over the past 12 months "*sometimes*", “*often*", or "*all the time*" (Case 2), the expert perceived no difference for FIOH points 2 and 10 while the workers themselves assessed these points significantly differently than their colleagues. For Case 2, workers in the two groups also provided significantly different assessments of the ergonomic quality of their workstation and the need for changes, while the expert noticed no significant difference.

It is interesting to note that the expert assessed the workstations more negatively than the workers themselves on all five topics covered by the FIOH assessment. Generally, the expert saw a greater need for modification than did the workers and assessed a workstation's ergonomic quality as lower than the workers themselves did.

Table 5.4

Comparison of the average worker and expert assessments based on reported pain in the past seven days and the past 12 months, according to 2 cases.

	Case 1		Case 2			
	Pain past 12 months		Pain past 12 months		Pain past 7 days	
	Workers	Expert	Workers	Expert	Workers	Expert
FIOH 1 Work site (expert scale : 4 level)	**21.72*** (447) p < 0.0001 [40.4 ; 49.5] (+)	3.63 (469) p < 0.0575 [72.5 ; 75.8]	3.17 (439) p < 0.0755 [40.3 ; 46.3] (+)	**6.90** (461) p < 0.0089 [66.43; 74.9]	**7.89*** (455) p < 0.0052 [40.0 ; 46.8] (+)	0.87 (477) p < 0.0912 [71.1 ; 75.1]
FIOH 2 General physical activity (expert scale : 4 level)	**19.01*** (447) p < 0.0001 [56.7 ; 65.5] (+)	1.01 (469) p < 0.3153 [65.5 ; 64.0]	**8.95***(439) p < 0.0029 [50.0 ; 62.1] (+)	0.04 (461) p < 0.8441 [65.0 ; 64.5]	**10.57***(455) p < 0.0012 [53.8 ; 63.0] (+)	1.79 (477) p < 0.1821 [67.1 ; 64.6]
FIOH 3 Lifting (expert scale : 5 level)	**30.31***(446) p < 0.0001 [41.8 ; 51.5] (+)	0.66 (469) p < 0.418 [47.6 ; 46.2]	**5.95** (438) p < 0.0152 [38.0 ; 47.5] (+)	**4.63** (461) p < 0.0319 [53.7 ; 46.2]	**4.98***(454) p < 0.0262 [42.3 ; 48.3] (+)	0.62 (477) p < 0.4313 [48.9 ; 46.9]
FIOH 4 Work postures and movements (expert scale : 5 level)	0.55 (444) p < 0.4575 [81.7 ; 82.3] (+)	**6.35** (466) p < 0.0121 [94.0 ; 90.8]	2.80 (436) p < 0.0948 [75.0 ; 81.9] (+)	0.01 (458) p < 0.9333 [92.0 ; 92.2]	**13.86***(452) p < 0.0002 [72.5 ; 83.3] (+)	0.11 (474) p < 0.7379 [92.0 ; 92.6]
FIOH 10 Repetitiveness (expert scale : 5 level)	1.78 (447) p < 0.1823 [80.3 ; 83.3] (+)	0.07 (469) p < 0.7919 [88.8 ; 88.4]	**6.13***(439) p < 0.0137 [70.0 ; 82.5] (+)	0.08 (426) p < 0.7733 [89.1; 88.2]	**5.07***(455) p < 0.0248 [75.8 ; 83.2] (+)	0.35 (477) p < 0.5523 [87.4 ; 88.6]
Ergonomic quality (scale : 0 to 10)	**22.57** (448) p < 0.0001 [62.1 ; 50.3] (+)	**6.76** (207) p < 0.01 [52.8 ; 44.1]	**12.48***(439) p < 0.0005 [71.9 ; 54.5] (+)	3.17 (206) p < 0.0765 [57.4 ; 47.1]	**6.56** (455) p < 0.0107 [63.5 ; 54.4] (+)	**5.23** (207) p < 0.0232 [57.1 ; 46.4]
Needs for changes (scale : 0 to 10)	**36.11** (446) p < 0.0001 [35.1 ; 52.5] (+)	**9.9** (207) p < 0.0019 [46.8 ; 58.6]	**7.53***(437) p < 0.0063 [29.5 ; 45.7] (+)	2.82 (206) p < 0.0945 [43.2 ; 54.2]	**12.2***(455) p < 0.0005 [32.0 ; 46.6] (+)	2.64 (207) p < 0.1058 [45.5 ; 54.2]

*Values in bold with an asterisk (*) indicate a statistically significant difference in the significance threshold $p < 0.05$ for the worker, and a not significant difference for the expert.
Values only in bold indicate a statistically significant difference in the threshold $p < 0.05$ for either the expert or the worker.
[;]: Values between brackets correspond respectively to the average percentage score for workers with no pain and the average percentage score for workers with pain
(n): number of observations included in the comparison

5.5 Discussion

5.5.1 Pain prevalence

While the goal of this study is not to compare the prevalence of musculoskeletal pain to that of a reference population, we have done so, using certain criteria, in order to better characterize the sample of workers with respect to reported pain. More than eight workers out of ten reported pain in at least one body region in the seven days preceding the data collection (Table 3). The workers reported more musculoskeletal disorder symptoms than the overall Quebec reference population (Daveluy et al., 2001). The significance of this result could not, however, be confirmed, since we could not collect information for each of the 11 body regions to create comparable data. For the entire sample, it was only possible to identify whether pain had been reported for at least one body region. Workers declared between 9% and 36% less pain in a 12-month reference period (Cas 1) compared to a 7-day period. The tree nursery sector reported the greatest difference (35.9%) between the two periods on which the workers were questioned. The seasonal character of the work in the tree-nursery sector can partly explain this result. With most production occurring between May and October, it is plausible that most symptoms disappear during the off season (November to April).

In spite of the fact that tree nurseries are the sector in which workers declared the least pain for the entire body over a 12-month period, tree nursery workers nonetheless reported more upper-limb pain (27.3%) than the reference population (20.6%) (Table 5.2). Workers in the two other sectors also reported significantly more pain in the upper limbs. Subjects from the appliances sector had a significantly higher prevalence of back pain than the reference population. These results can be explained by the fact that the workers in the sample were probably more exposed to MSD risk factors than the general population since the nature of the work in all three sectors strains the upper limbs. In the appliances sector, a high proportion of workstations involve static postures that are held for long periods of time and working heights that are too low (Chiasson et al. 2011). In fact, the workstations assessed for this study were chosen either because they had been targeted by CSST (Quebec's Workers' Compensation Board) inspectors as having a history of MSDs or because the company had identified them as workstations at risk for causing MSDs or following workers' complaints.

As other studies have demonstrated, women tend to have a higher prevalence of symptoms than men (Zetterberg et al., 1997). However, despite the greater proportion of female study participants in the tree nurseries, the pain reported for the 12-month period was not significantly different from that observed in the two other sectors when compared to the reference population.

Landen and Hendricks (1995) found that recall errors can skew retrospective pain-report findings when the reference period is too long. An underestimation of the pain experienced during the 12-month period might therefore be a possibility. In other words, a larger proportion of workers could actually have experienced pain in the 12 months prior to the data collection. However, for a shorter reference period, such as the pain reported for the previous seven days, there is a reduced possibility for memory bias.

5.5.2 Pain reported and perception of the workstation

5.5.2.1 Assessment using the FIOH method

According to the expert's assessment, the workstations all presented risks, with the average FIOH scores indicating a moderate to high risk of developing MSDs. The sample of workstations assessed rated an average score that varied in percentage from 46.2 to 94%. Work postures and movements received an average score above 90% in all the comparisons. The workstations examined for this study thus presented significant MSD risk factors.

While the scores of the workers from the two groups (with and without pain) varied between 40% and 83.3%, the expert rated them 2% to 35% higher, depending on the FIOH point being assessed. This finding clearly illustrates that the expert did not come to the same conclusions as the workers regarding risks at the workstations and assessed them more severely, on average.

The workers who had reported pain in the seven days prior to the workstation assessment evaluated their workstation more negatively. The scores of the workers in the group with no pain were an average of 7% to 11% lower than those of the group who reported pain. The FIOH points related to MSDs such as work site, general physical activity, lifting, repetitiveness, work posture and movements were assigned significantly higher scores by workers who reported pain. This negative perception appears to be unrelated to the task and its components since the expert's assessment did not signal any significant difference between the workstations of the two groups of workers.

With respect to the pain reported in the past 12 months (Cases 1 and 2), average scores were also all higher for the group of workers reporting pain. However, the less significant results might be explained by a reference period that is too long, and work characteristics unique to the tree nursery sector (i.e. seasonal work). Our findings show that the impact of pain reported close to the time the worker is questioned about his/her workstation seems to make a more significant difference.

The results presented for the 12-month period (Case 2) are probably less reliable. Over 90% of workers in the three sectors reported some pain in this case, leaving few subjects who reported no pain. This large imbalance between the two groups of workers for Case 2, may cause difficulties with the statistical test.

Donders et al. (2007) explain their findings by noting that people suffering from pain or chronic disease perceive their job as more difficult because they feel more vulnerable. Hays et al. (1996) suggest that workers may experience a heavier workload because pain or health problems lead them to perceive it as greater. In other words, the subjects of our study could have assessed their workstation more severely because they think their pain is due to poor workstation design or because their pain makes it harder for them to occupy their workstation.

5.5.2.2 Workstation ergonomic quality and the need for changes

For all the comparisons made using VAS scale scores (i.e. ergonomic quality and the need for changes), the results show a statistically significant difference between workers reporting musculoskeletal pain and those reporting no pain for the 12-month and 7-day periods.

Unlike the results obtained from the FIOH method, in this instance the expert noted a significant difference in the ergonomic quality of the workstations occupied by workers reporting pain and those workers who reported no pain over the 12-month and 7-day periods for Case 1. While this result is harder to explain, it may be that the expert's subjective assessment of the workstation takes into account factors not considered by the FIOH method's topics used here.

In contrast to a workstation's ergonomic quality, the need for changes may be easier to assess on a VAS scale. Workers who are in pain may have already thought of possible changes to their workstation to reduce the workload. In other words, if the worker believes that their pain is related to a poorly designed workstation, they would regard workstation modifications as essential to reducing pain. Since the expert assessment corresponds to that of the workers in both groups, it does not show a significant difference between the group of workers who reported pain and the group who reported no pain in a 7-day period. These findings suggest that the perceived need for changes is related to the worker's perception and not to an actual need for changes to the workstation.

Finally, it is also plausible to hypothesize that the workers had been influenced by their interview with the expert when they answered these two questions. The FIOH method was administered before the VAS scale was used to assess the workstation’s ergonomic quality and need for changes. Workers from both groups could therefore have been influenced one way or another since their knowledge of ergonomics increased as the interview progressed.

Although the study shows that an experience of musculoskeletal pain can negatively affect the worker's perception of a workstation, workers’ opinions remain necessary to provide a better understanding of the work situation. Although this information is subjective, it helps to collect data that is otherwise difficult to obtain through workstation observation alone (Chiasson et al., 2011). The process of administering the FIOH also helps provide a basis for discussing workstation strengths and weaknesses with workers. For example, the poor quality of a hand coupling on a load being handled at work is a good example of the type of information that can be obtained when collecting the worker's perception of the effort required to perform a task. It is the type of information needed when planning an ergonomic intervention to improve a workstation. Since no single method seems perfect for assessing risk (Burdorf and van der Beek, 1999), an approach that combines several methods would seem preferable (Chiasson et al., 2011 ; Stock et al., 2005). However, the findings highlight the importance of considering the opinions of more than one worker when a method that takes into account the worker's perception is used to determine the risk level of a workstation.

5.5.3 Limitations and future work

The manner of administering the questionnaires may have influenced the workers' responses regarding the perception of their workstations. It also would have been beneficial to have even more workstations with multiple workers. The tree nursery sector provided this option for the majority of its workstations in the sample, but the number of workers able to answer questions about the same workstation in the two other sectors studied was more limited. Further studies should be conducted with a larger sample of workstations and workers. The sample should be comprised of workstations considered of concern for MSDs as well as lower-risk workstations and include more subjects in good health.

5.6 Conclusion

This study measured the impact of pain on workers' perceptions of their workstations. The findings show that workers reporting pain assessed their workstations more negatively with respect to certain aspects related to ergonomic risk factors as measured by the FIOH *Ergonomic Workplace Analysis* method, developed for practitioners. More specifically, workers who reported pain in the seven days preceding the workstation assessment assigned significantly higher scores for MSD-related risk factors than workers who reported no pain. Those reporting pain also perceived their workstation to be of lower ergonomic quality and indicated a greater need for its improvement. The expert's ratings were systematically more severe than those of the workers on the same topics. Finally, it is interesting to note that the expert's overall assessment of a workstation's ergonomic quality seemed to take into account aspects that were not reflected in the five FIOH method topics used. These results highlight the importance of having the practitioner collect assessments from more than one worker when possible for each workstation being analyzed and check whether these respondents have reported pain in the preceding seven days. The findings also indicate that from an MSD prevention point of view, an ergonomics expert assessment may be more suitable to detect at risk workstations.

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CHAPITRE 6 : DISCUSSION GÉNÉRALE ET CONCLUSIONS

L'objectif des deux premières études de cette thèse était de comparer les résultats que produisent des méthodes d'évaluation des facteurs de risque de TMS. Dans le cadre de cette recherche, les résultats de 21 indices tirés de 11 méthodes basées sur l'observation ont été comparés en les appliquant à un échantillon de 224 postes de travail comptant 567 tâches différentes. À l'exception des études de Kee et Karwowski (2007) et Spielholz et al. (2008), comparant respectivement trois et deux méthodes, les comparaisons sont généralement faites sur des échantillons de petite taille. Par exemple, l'étude de Jones et Kumar (2010) compare cinq méthodes permettant d'évaluer les facteurs de risque de TMS aux membres supérieurs avec un échantillon de quatre postes de travail. Russell et al. (2007) comparent aussi cinq méthodes permettant d'évaluer le risque au dos, cependant elles sont appliquées à une tâche de manutention manuelle unique. Notre étude aura permis de comparer 11 méthodes sur un grand échantillon de postes. L'ampleur de la collecte de données dans le cadre de cette recherche confère une robustesse aux résultats présentés dans cette thèse. Effectuée dans 18 usines de secteurs industriels variés, elle comporte aussi un avantage par rapport à d'autres études réalisées dans un milieu de travail unique ou pour une tâche en particulier (Lavender et al. 1999 ; Russell et al. 2007). Elle nous a permis de comparer les méthodes sur une grande variété de situations de travail.

Au chapitre 3 de la thèse, la première étude présente une analyse comparative des résultats de six méthodes permettant d'évaluer les facteurs de risque de TMS au dos. La deuxième étude, présentée au quatrième chapitre, se penche sur deux groupes de méthodes. Dans un premier groupe, les méthodes permettant d'évaluer les facteurs de risque de façon plus globale ou pour plus d'une zone corporelle sont comparées. Dans un deuxième groupe, les méthodes permettant d'évaluer les facteurs de risque aux membres supérieurs sont comparées entre elles. Les deux études permettent d'évaluer les niveaux de risque obtenus à partir des différentes méthodes. Puisque celles-ci ont des échelles de mesure du risque qui leur sont propres, il a fallu définir des échelles d'équivalences de manière à pouvoir les comparer entre elles. Les méthodes ont ainsi été comparées selon trois catégories de risque : faible, modéré et élevé. Les échelles d'équivalence sont définies plus en détail aux chapitres 3 et 4 de la thèse. La troisième étude (chapitre 5) étudie le lien entre la déclaration de la douleur et la perception des travailleurs quant à l'évaluation de leur poste de travail. L'objectif est de déterminer si le fait de déclarer des douleurs musculo-squelettiques a un lien avec la perception qu'a le travailleur de son poste de travail quant aux facteurs de risque liés à l'ergonomie, tels qu'évalués par la méthode *Ergonomic Workplace Analysis* développée par le FIOH à l'intention des praticiens.

Les résultats de cette thèse et les conclusions qui en découlent ont pour objectif de fournir aux utilisateurs des informations qualitatives et quantitatives qui sauront mieux les outiller quant au choix d'une méthode. Les résultats de ces trois études seront passés en revue et discutés dans la première partie de ce chapitre. Dans une deuxième partie, les choix méthodologiques ainsi que les limites des études seront traités. Malgré l'étendue des résultats contenus dans les trois articles composant cette thèse, plusieurs autres pistes de recherche se présentent toujours à nous pour mener des travaux futurs afin d'approfondir les connaissances sur les méthodes d'évaluation des facteurs de risque de TMS. Ces pistes de recherche seront abordées dans la dernière partie de ce chapitre.

6.1 Évaluation des facteurs de risque de TMS à partir des méthodes d'observation

Le chapitre 3 analyse des résultats obtenus à partir de 11 indices évaluant le risque au dos tirés des méthodes FIOH, Mital et al. (1997), QEC, EN 1005-3, 3D SSPP et 4D WATBAK. Pour la deuxième étude, au chapitre 4, cinq méthodes permettant d'évaluer les facteurs de risque aux membres supérieurs sont comparées (HAL, JSI, OCRA, EN 1005-3 et QEC) ainsi que quatre méthodes évaluant les facteurs de risque de façon plus globale ou pour plus d'une zone corporelle (FIOH, QEC, REBA et RULA). Dans les deux études, la norme EN 1005-3 ressort comme étant la méthode la plus sévère par rapport aux autres méthodes évaluant le risque au dos et aux membres supérieurs. Parmi les paires de méthodes comparées, près de la moitié des méthodes évaluant le risque au dos montraient des écarts de deux niveaux de risque pour un poste sur cinq. Plus de la moitié des paires de méthodes évaluant le risque aux membres supérieurs, présentent un taux de désaccord de deux niveaux de risque pour une proportion des postes variant de 6 à 25%. La comparaison des méthodes par groupe homogène révèle des écarts parfois significatifs entre les méthodes d'un même groupe. Aucune paire de méthodes ne semble en accord parfait.

Globalement, les résultats présentés dans les chapitres 3 et 4 permettent de constater qu'un poste de travail peut être considéré à risque par une méthode et ne pas l'être par une autre. Les résultats contenus dans ces chapitres illustrent les conséquences potentiellement importantes du choix d'une méthode sur la détermination des priorités dans le cadre d'une intervention de dépistage des postes les plus à risque dans une entreprise.

Dans l'ensemble de l'échantillon de postes de travail, l'évaluation des facteurs de risque de TMS à partir des méthodes démontre qu'une plus grande proportion de postes à risque est identifiée par les méthodes évaluant les facteurs de risque de TMS aux membres supérieurs. Au chapitre 5, les résultats montrent aussi que les travailleurs déclarent significativement plus de douleurs musculo-squelettiques aux membres supérieurs dans les trois principaux secteurs de l'étude (i.e., assemblage d'électroménagers, pépinières forestières et fabrication de produits de plastique et de composites) que dans la population de référence du Québec (ESS98, ISQ, 2001) pour une période de rappel de 12 mois. Il semble donc y avoir un lien entre la déclaration de douleurs aux membres supérieurs et l'évaluation des facteurs de risque.

Le coût d'utilisation de certaines méthodes peut constituer un frein pour le praticien ou l'entreprise qui désire adopter une méthode. L'analyse des méthodes en fonction de l'identification des priorités d'intervention (i.e., identifier les postes considérés comme étant les plus à risque par une méthode) a permis de montrer que certaines méthodes demandant moins d'effort peuvent produire des résultats semblables quant à l'identification des postes à risque. Par exemple, l'indice QEC pour les mains et poignets permet d'identifier 74% des postes aussi identifiés par la méthode OCRA pour la même zone corporelle. L'écart d'effort exigé par la méthode OCRA comparativement à la méthode QEC est considérable (Aubry 2006 ; Malchaire 2001). Il semble ici qu'une méthode qui permet une analyse plus simple et exigeant une collecte de données beaucoup moins importante pourrait constituer un substitut intéressant à une méthode plus complexe à utiliser et demandant beaucoup plus de ressources. À titre d'exemple, notre expérience sur le terrain a permis de constater qu'en moyenne l'utilisation de la méthode OCRA a nécessité plus de 4 heures pour réaliser une évaluation de poste étant donné qu'elle demande une étude de temps. En comparaison, le temps nécessaire pour compléter toutes les sections de la méthode QEC a été, en moyenne, de moins d'une demi-heure, soit moins de 1/8 du temps pour obtenir 3/4 du résultat.

L'analyse des résultats montre aussi que certaines méthodes pourraient être privilégiées par rapport à d'autres si une approche plus conservatrice était recherchée. C'est le cas de la méthode JSI qui pourrait être privilégiée par rapport à la méthode HAL. Les résultats montrent que JSI a identifié 97% des postes considérés à risque élevé par HAL.

Certaines méthodes font une évaluation de risque en fonction du travail au poste alors que d'autres font une évaluation du risque qui peut être influencée par des facteurs autres que la conception du poste lui-même (Lavender et al. 1999). Ceci soulève des questions quant au choix d'une méthode pour comparer des postes entre eux. C'est le cas de 3D SSPP et 4D WATBAK qui évaluent le risque à partir de la posture d'un travailleur qu'on observe et donc tiennent compte des caractéristiques individuelles du sujet (poids, taille, sexe) et de sa façon de travailler. D'un autre côté, cet aspect est intéressant pour un praticien qui veut évaluer la charge de travail d'une personne en particulier à un poste (ex. travailleur ayant des limitations fonctionnelles). En utilisant une méthode comme les tables de Mital et al. (1997), cette possibilité est évacuée.

Bien que les résultats des études montrent que certaines méthodes peuvent être équivalentes pour une première étape de dépistage des postes les plus à risque (ex. QEC par rapport à OCRA), il reste qu'elles sont complémentaires dans le cadre d'une intervention plus large visant la réduction de l'exposition aux facteurs de risque de TMS. Une entreprise pourrait décider d'utiliser la méthode QEC dans un premier temps pour identifier les postes où elle devrait effectuer des changements en priorité, puis utiliser la méthode OCRA afin de réaliser une analyse plus fine aux postes prioritaires puisqu'elle tient compte de plus de variables dans la détermination de l'indice de risque. Également, le moment au dos obtenu à partir d'un calcul biomécanique en combinaison avec la norme EN 1005-3 fournit une combinaison intéressante de méthodes qui permet de prendre en compte un plus grand nombre de variables.

Étant donné les résultats contradictoires que fournissent certaines paires de méthodes, l'utilisation de la même méthode devient importante lors d'une intervention où l'on voudrait effectuer une comparaison du niveau de risque avant et après avoir réalisé des transformations à un poste de travail. D'autres analyses permettraient aussi de déterminer si une méthode est plus sensible qu'une autre pour détecter un changement dans les niveaux de risque avant et après transformations.

Jones et al. (2005), Marras et al. (1999), Waters et al. (1993, 1998), ont montré qu'une évaluation complète devrait se faire en utilisant plus d'une méthode. Un poste de travail peut compter des facteurs de risque non considérés par certaines méthodes. Le choix de la méthode devrait être fait en fonction de l'objectif de l'intervention (ex. établir une priorité d'intervention, obtenir de l'information plus détaillée sur le poste ou déterminer une valeur seuil afin de réaliser des transformations à un poste de travail, comme c'est le cas avec le Guide de Mital et al. (1997) ou la norme EN 1005-3). Même si les résultats montrent que certaines méthodes semblent beaucoup moins sévères, comme c'est le cas avec les indices de compression lombaire, de cisaillement et du moment au dos pour 3D SSPP et 4D WATBAK, la comparaison des valeurs brutes avant et après transformations au poste de travail nous fournirait probablement une information utile sur l'appréciation des modifications apportées.

L’utilisation de plus d’une méthode peut non seulement aider à prioriser les interventions mais aussi à évaluer des facteurs de risque non pris en compte par l’une ou l’autre des méthodes. Si l’on choisit d’utiliser plus d’une méthode, la séquence dans laquelle on devrait les appliquer devient importante. Certaines méthodes moins sévères telles que 3D SSPP ou 4D WATBAK ne fourniraient possiblement que peu d’informations supplémentaires intéressantes quant à la priorité d’intervention si elle étaient appliquées après la méthode QEC par exemple. Toutefois, l'utilisation de plus d'une méthode peut rapidement engendrer un coût prohibitif pour le praticien. Aucune information n’est disponible dans la littérature en ce qui concerne la complémentarité des méthodes.

6.2 Effet de la douleur sur la perception des travailleurs

La troisième étude (chapitre 5) a permis de constater le lien entre la douleur et la perception qu’a le travailleur de son poste de travail. Les résultats principaux du chapitre montrent que les travailleurs déclarant de la douleur perçoivent de façon plus négative leur poste de travail pour certains facteurs de risque liés à l'ergonomie tels que mesurés à partir de la méthode *Ergonomic Workplace Analysis* du FIOH. L’analyse des déclarations de douleur et l’évaluation de la perception du travail ont été réalisées en fonction d’une période de rappel de 12 mois et une période de rappel de sept jours précédant l’évaluation du poste. Plus spécifiquement, les travailleurs ayant déclaré des douleurs au cours des sept jours précédant l’évaluation du poste accordent un pointage évaluant le risque au poste significativement plus élevé que leurs collègues ne déclarant pas de douleur (cette évaluation portant sur des facteurs de risque liés aux TMS). Les travailleurs déclarant des douleurs perçoivent que leur poste a une qualité ergonomique moindre et indiquent un plus grand besoin de l'améliorer. En ce qui concerne la déclaration de douleurs au cours des 12 derniers mois, les moyennes des pointages sont aussi toutes plus élevées dans le groupe de travailleurs déclarant des douleurs. Toutefois, les résultats moins significatifs peuvent être expliqués par la période de référence qui est trop longue, en plus des caractéristiques qui sont propres aux secteurs des pépinières (i.e. travail saisonnier). La déclaration de douleur sur une aussi longue période peut être une méthode de mesure moins fiable. Landen et Hendrick (1995) rapportent que le biais de mémoire peut influencer les résultats des déclarations de douleurs lorsque la période de référence est plus longue.

Donders et al. (2007) rapportent que la perception d'un travail plus difficile chez les personnes souffrant de douleurs ou de maladies chroniques était due au fait qu'elles se sentaient plus vulnérables. Hays et al. (1996) suggèrent que les travailleurs peuvent ressentir une charge de travail plus élevée à cause des douleurs dont ils souffrent ou parce que leurs problèmes de santé les conduisent vers une perception d'une charge de travail plus élevée. En d'autres mots, les sujets de notre étude auraient évalué leur poste de façon plus sévère à partir de la méthode du FIOH en pensant que leurs douleurs étaient causées par une conception de poste de travail déficiente ou parce qu'ils avaient plus de difficulté à occuper leur poste de travail à cause des douleurs dont ils souffraient.

L'évaluation d'un expert est probablement préférable lorsqu'il s'agit d'identifier les postes à risque. Les résultats de notre étude démontrent que l'opinion du travailleur est moins fiable, puisqu'elle varie selon la présence de douleur ou non et sont en accord avec d'autres études (Leijon et al. 2002, Viikari-Juntura et al. 1996 ; Wiktorin et al. 1993). En fait, dans un contexte de mobilité des travailleurs entre les postes ou de la pratique de la rotation des postes de travail dans une entreprise, un travailleur atteint de douleurs risquerait d'évaluer le poste qu'il occupe plus négativement alors qu'en réalité l'apparition de douleurs pourrait être reliée à un poste occupé précédemment. Cela ferait en sorte qu'un poste pouvant être plus à risque pour le développement des TMS pourrait être évalué comme ayant de meilleures qualités ergonomiques si le travailleur qui l'occupe au moment de l'évaluation ne déclare pas de douleur alors qu'un poste moins à risque pourrait être évalué plus négativement si le travailleur qui l'occupe ressent des douleurs. En se basant plutôt sur une évaluation faite par un expert, ces biais sont évités.

Les résultats de la troisième étude sont aussi appuyés par ceux produits dans la deuxième étude. En comparant le résultat de la méthode du FIOH, combinant à parts égales l'évaluation du travailleur et celle de l'expert, aux autres méthodes du même groupe, on constate que cette méthode classe effectivement moins de postes dans la catégorie de risque élevé par rapport à RULA et REBA. L'utilisation de la méthode sans la considération de l'opinion des travailleurs produirait probablement des résultats se rapprochant plus des méthodes RULA et REBA. L'utilisation de la méthode du FIOH telle que faite dans notre étude (i.e., combinant à part égale l'évaluation du travailleur et celle de l'expert), ne serait donc pas recommandée dans une démarche de prévention visant l'identification des postes les plus à risque.

Toutefois, même si cette information est "subjective", l'opinion du travailleur permet de recueillir de l'information qui est, autrement, difficile voire impossible à obtenir avec une méthode se basant uniquement sur l'observation du travail. Le questionnaire que l'on administre aux travailleurs dans le cas de la méthode du FIOH permet d'avoir une base pour discuter avec les travailleurs des points forts et des points faibles de leur poste de travail. Par exemple, la mauvaise qualité d'une prise sur une charge à manutentionner dans le cadre d'un travail illustre bien le genre d'information qu'il est possible d'obtenir en recueillant la perception du travailleur sur l'effort qu'il doit fournir pour accomplir sa tâche. Ce genre d'information est recherché lorsque vient le temps de mener une intervention ergonomique visant à améliorer un poste de travail. Suite à ces constats, une approche combinant plusieurs méthodes de mesure devrait être privilégiée (Stock et al. 2005).

6.3 Choix méthodologiques pour la comparaison des méthodes

Le choix des méthodes s'est fait dans une perspective de facilité d'utilisation et d'accessibilité. Elles sont susceptibles d'être utilisées par des non-chercheurs d'expertise variable en ergonomie. D'ailleurs, dans le cadre de cette étude, elles ont toutes été appliquées à un échantillon de postes, tel qu'elles auraient été utilisées par un praticien, en respectant les recommandations proposées par les auteurs des méthodes.

Les comparaisons des méthodes se basent sur des catégories de risque. Le choix de ces catégories est en accord avec celles proposées par les auteurs des méthodes ou en accord avec les recommandations dans la littérature scientifique (Jones et Kumar 2010 ; Kee et Karwowski 2007 ; Lavender et al. 1999 ; Russell et al. 2007). Aux fins de cette étude, ce choix est justifié par le fait que la comparaison se veut le plus proche possible de la réalité des praticiens, utilisateurs de ces méthodes. Ce sont donc des catégories de risque qui sont susceptibles d'être utilisées par eux. Étant donné que le nombre de catégories de risque diffère d'une méthode à une autre, certaines catégories de risque ont été regroupées lorsque la méthode en proposait plus de trois. Ces choix s'inscrivent dans une perspective d'intervention. Les valeurs seuils de la catégorie de risque élevé ont été choisies sachant qu'une intervention au poste de travail doit être réalisée lorsqu'un risque important est présent et donc l'entreprise doit apporter des modifications au poste de travail. Par conséquent, si les regroupements de catégorie de risque utilisés ici, basés sur d'autres travaux de recherche, avaient été différents, ils auraient sans aucun doute mené à des résultats différents en termes de répartition des postes selon les niveaux de risque.

D'autre part, une limite importante réside dans le fait que les liens entre les données épidémiologiques et les catégories de risque restent inconnus. Non seulement les catégories de risque équivalentes entre les méthodes comparées peuvent faire l'objet de débats, mais la division qui est faite dans les valeurs produites pour une méthode (i.e., selon les valeurs seuils choisies par les auteurs des méthodes), le peut aussi. Idéalement, les valeurs seuils seraient établies en fonction de la prévalence des TMS aux postes de travail. Pour l'instant, de tels résultats ne sont pas disponibles. Nous n'avions ainsi d'autre choix que de nous baser sur les recommandations des auteurs qui, eux, se sont en principe appuyés sur des recherches antérieures pour développer leurs méthodes. Par conséquent, les résultats ne nous permettent pas de déterminer quelle méthode ou quel choix de catégories de risque permet le mieux de prédire le risque réel. L'estimation du risque réel en termes de taux d'incidence des blessures musculo-squelettiques à chacun des postes étudiés aurait nécessité un effort colossal qui dépassait largement le cadre de cette étude (Jallon 2011).

Lorsque vient le temps d'effectuer des comparaisons entre méthodes, une autre difficulté réside dans le fait que certaines d'entre elles ont été développées pour analyser une tâche plutôt qu'un poste (ex. FIOH vs RULA). Kee et Karwowski (2007), par exemple, comparent les méthodes OWAS, REBA et RULA avec des données qui proviennent d'un échantillon de 301 postures. Toutefois, cette situation ne correspond pas toujours à la réalité de l'utilisateur. L'utilisateur voudra évaluer le poste et pas seulement une unique posture lors de l'une des multiples activités réalisées au poste. C'est sur cette base que nos choix méthodologiques ont été faits. Le choix d'évaluer les tâches les plus difficiles aux postes de notre échantillon nous semblait la façon la plus raisonnable de procéder et celle qui correspondait le plus à ce qu'un praticien aurait probablement fait. C'est aussi ce choix que Jones et Kumar (2010) ont fait dans leur étude. La méthode QEC par exemple, à laquelle les méthodes RULA et REBA ont été comparées, bien qu'elle fournisse une évaluation pour le poste dans son ensemble, ses auteurs recommandent de se baser aussi sur la posture la plus critique pour l'analyse du poste (David et al. 2008).

Quant au choix d'utiliser la valeur la plus élevée (peak value) pour les comparaison avec les logiciels de modélisation biomécanique 3D SSPP et 4D WATBAK, les résultats montrent que malgré le fait d'avoir choisi de comparer les valeurs les plus élevées pour la compression, le cisaillement lombaire et le moment au dos, ces méthodes ressortent toujours comme étant moins sévères que les autres méthodes évaluant le risque au dos.

Afin de comparer une méthode comme celle du FIOH, certains choix méthodologiques ont dû être faits. Étant donné que les auteurs de la méthode ne proposent pas de façon de combiner l'évaluation des 14 items en un indice global ou intégré, ceci rend la comparaison plus difficile avec les autres méthodes. Si cette méthode est utilisée pour le dépistage des postes les plus à risque parmi un ensemble de postes, cela complique aussi les choses pour le praticien. Toutefois, étant donné que la méthode permet d'évaluer 14 items très variés (ex. contrainte thermique, posture et mouvements, communication et contacts personnels, etc.), un indice global ne nous permettrait pas de détecter un risque élevé quant aux facteurs de risque de TMS à un poste. L'indice global pourrait ne pas faire ressortir cet aspect d'un poste particulier par rapport à d'autres postes qui auraient pu obtenir le même pointage, mais pour des facteurs de risque bien différents (ex. contrainte thermique ou bruit). L'avantage d'une méthode comme le QEC, c'est qu'elle permet d'obtenir un indice global, mais aussi un indice spécifique à chacune des zones corporelles. Comme la littérature ne fournit pas d'information quant aux facteurs de risque les plus dommageables pour les TMS, le regroupement des items de la méthode du FIOH, qui sont en lien avec les facteurs de risque de TMS, en un indice intégré sans appliquer de pondération aux éléments constitutifs, nous semblait approprié pour effectuer les comparaisons avec les autres méthodes. Des résultats de recherches futures pourront peut-être nous permettre de déterminer une pondération pour les 4 items constitutifs en lien avec les TMS pour cette méthode (i.e., poste de travail, posture et mouvements, levée de charge et répétitivité).

Dans l'ensemble, malgré les limites inhérentes à toute étude fondée sur des comparaisons, nous avons pu dégager plusieurs résultats novateurs en comparant 11 méthodes, ce qui nous permet ainsi de contribuer aux connaissances scientifiques ayant trait aux méthodes d'évaluation des facteurs de risque de TMS à un poste de travail.

6.4 Recherches futures

6.4.1 Méthodes d'évaluation des facteurs de risque de TMS

L'analyse de la contribution de chacune des variables dans une méthode en lien avec la détermination du niveau de risque permettrait de faire des suggestions quant à de nouvelles pondérations. D'ailleurs, les résultats présentés au chapitre 4 montrent bien que la pondération des variables pour les méthodes OCRA et EN1005-3 semble parfois problématique. Par exemple, pour la norme EN 1005-3 intégrant un plus grand nombre de variables dans son calcul par rapport aux autres méthodes pour le dos et pour les membres supérieurs, il est possible de penser que les pondérations utilisées pour chaque variable sont pénalisantes tel que le montrent les résultats des deux premières études. La norme EN 1005-

3 a classé neuf postes sur 10 dans la catégorie de risque élevé pour l'articulation de l'épaule et pour le dos. El ahrache et Imbeau (2009) observent que les schèmes discontinus de pondération de la norme pourraient entraîner des évaluations plus sévères dans certains cas. L'analyse des distributions des indices au chapitre 4 montre bien cet effet. Un problème se pose aussi pour la méthode OCRA. Les résultats obtenus avec certaines conditions présentes au poste peuvent mener à des indices extrêmes. Lorsqu'un pointage de « 5 » ou plus sur l'échelle de Borg est accordé par le travailleur pour un élément de la tâche dont la durée est supérieure à 10% du temps, le facteur force qui doit être appliqué est de 0.01, ce qui a pour effet d'augmenter considérablement l'indice OCRA (Aubry 2006). Ce facteur est donc extrêmement pénalisant et l'impact sur le pointage final est immense. Ces résultats pourraient servir de base pour le développement d'une méthode modifiée.

Des analyses détaillées en fonction du type de tâche ou de la nature du travail permettraient probablement de préciser le cadre d'utilisation de chacune des méthodes et leurs limites (David 2005). Une analyse des résultats en fonction du type de travail réalisé au poste ou selon des sous-groupes de tâches (i.e., assis, debout, avec ou sans manutention, variations importantes dans la posture) tel que proposée par Kee et Karwowski (2007), nous permettrait de déterminer si les résultats des méthodes se comparent de la même façon entre eux. Est-ce que les mêmes priorités d'intervention sont identifiées? Une telle analyse nous permettrait de déterminer si certaines paires de méthodes obtiennent un taux de désaccord différent. Li et Buckle (1999a) mentionnent un problème supplémentaire relié à l'utilisation de certaines méthodes à l'effet qu'elles ont souvent été développées dans un contexte de recherche bien précis. Pour cette raison, elles peuvent parfois être peu fiables lorsqu'appliquées dans un contexte différent (ex., pratique en ergonomie) comme c'est le cas de RULA qui serait difficilement adaptée pour une situation de travail hautement varié.

Finalement, la base de données contenant des information détaillées sur plus de 200 postes de travail qu'aura permis de constituer cette recherche pourra aussi permettre de tester sur un large échantillon d'autres méthodes basées sur l'observation. La méthode QEC par exemple, adoptée par la CSST dans le cadre de son plan d'intervention sur les TMS, a été modifiée par cette organisation. Les valeurs seuils ont été revues à la hausse, la rendant moins sévère. Sans aucun doute, il sera très intéressant de comparer la méthode QEC modifiée par la CSST aux autres méthodes. Certaines entreprises et organisations sectorielles paritaires qui font le choix d'adopter des méthodes d'observation différentes de celles comparées dans le cadre de ce projet pourront les tester avec notre échantillon afin d'être en mesure de mieux comprendre les résultats qu'elles produisent par rapport aux autres méthodes. Par exemple, une entreprise provenant d'un secteur semblable à ceux de notre étude, qui fait le choix d'adopter une méthode dans le cadre d'une stratégie de prévention, pourrait voir un intérêt à ce que sa méthode soit comparée à d'autres quant à la détermination des postes les plus à risque à partir de notre base de données.

Notre expérience au cours de ces quatre années sur le terrain nous a démontré qu'encore plusieurs questions sur l'utilisation des méthodes d'observation lors d'interventions en ergonomie restent sans réponse. Considérant ces résultats, la recherche devrait se poursuivre pour développer un outil d'aide à la décision quant au choix d'une méthode d'évaluation des facteurs de risque de TMS (David 2005). Cet outil devrait guider le choix d'une ou plusieurs méthodes selon le type d'intervention et selon la nature du travail effectué au poste, mais aussi conseiller l'utilisateur sur la séquence dans laquelle les méthodes devraient être utilisées si le choix se porte sur plusieurs. L'outil devrait aussi fournir à l'utilisateur des recommandations quant à l'interprétation des résultats qu'on obtient avec une méthode. Nos résultats montrent que certaines méthodes donnent des résultats semblables quant à l'identification des priorités d'intervention tout en exigeant moins de ressources. Les résultats produits dans cette thèse peuvent déjà alimenter le développement d'un tel outil. Même si quelques études[2] ont déjà procédé à des analyses qualitatives sur les méthodes d'observation et que certaines ont aussi produit des résultats quantitatifs[3], aucun document ou outil regroupant tous ces résultats n'est encore disponible pour les organismes responsables de la prévention, les entreprises et les praticiens. Un tel document ou outil faciliterait grandement le choix d'une méthode d'observation pour les non-chercheurs qui ont peu de temps et qui n'ont pas toujours accès à toute la littérature scientifique qui traite de ce sujet. Il serait donc utile que les résultats générés par la recherche en ergonomie soient accessibles aux non-chercheurs à travers un tel outil d'aide à la décision. Idéalement, cet outil d'aide à la décision devrait être conçu pour intégrer le fruit de toutes ces recherches.

Dempsey et al. (2005), ont sondé des ergonomes professionnels certifiés afin de mieux connaître les outils et méthodes qu'ils utilisent. Leur étude nous informe quant à ceux les plus fréquemment utilisés par les praticiens. Les ergonomes interrogés devaient aussi indiquer pourquoi ils utilisent un outil ou une méthode plutôt qu'une autre. L'une des réponses possibles du questionnaire de Dempsey et al. (2005) était que la méthode est utilisée parce qu'elle est appropriée. Il serait intéressant de connaître les raisons pour lesquelles une méthode apparaît plus appropriée qu'une autre selon les praticiens, pour quels types d'intervention les méthodes sont utilisées et quel est le processus décisionnel

[2] David (2005), Malchaire (2001) ; Takala et al.(2010).

[3] Apostoli et al. (2004) ; Bao et al. (2006) ; Burdorf et Laan (1991), Drinkaus et al. (2003) ; Jones et Kumar (2007) ; Jones et Kumar (2010) ; Joseph et al. (2011), Kee et Karwowski (2007), Lavender et al. (1999), Marklin et Wilzbacher (1999), Marras et al. (1999), Russell et al. (2007), Sala et al. (2010) ; Spielholz et al. 2008 ; van der Beek et al. (2005) et Waters et al. (1998).

d’un praticien pour choisir une méthode. Quelles combinaisons de méthodes sont utilisées? Est-ce que des adaptations aux méthodes sont faites ? La façon d’utiliser la méthode varie-t-elle selon le contexte de l’intervention, selon le stade de l’intervention ? Dans le cadre de travaux futurs, il serait à propos de rassembler et comparer les avis sur l’efficacité d’une méthode selon l’expérience de chacun. Les chercheurs entreprennent souvent leur travail sans réellement connaître ce qu’en feront les utilisateurs sur le terrain. Des réponses à ces questions contribueraient sans doute à enrichir la littérature sur l’intervention en ergonomie et à cibler davantage celle-ci.

6.4.2 Perception des travailleurs

Quant au volet sur la perception des travailleurs (chapitre 5), il serait intéressant d’explorer quels sont les effets de l’ancienneté au poste de travail sur la perception qu’ont les travailleurs des risques liés à l’ergonomie. Sont-ils désensibilisés au risque comme cela se voit pour d’autres risques (ex. risque électrique) ou ont-ils plutôt une meilleure connaissance des faiblesses de leur poste ?

Notre expérience montre que la méthode du FIOH est une méthode qui permet de recueillir de l’information utile sur les postes de travail auprès des travailleurs qui les occupent. Toutefois, le questionnaire développé à l’intention des travailleurs devrait être étudié. Nos nombreuses entrevues avec ceux-ci nous ont amené à nous interroger sur la façon dont les questions sont formulées. Il serait intéressant d’explorer la manière dont la perception du travailleur peut être influencée par la formulation même de la question (Spielholz et al. 2001).

Par ailleurs, notre échantillon de travailleurs et de postes nous permettrait de comparer la cohérence dans les réponses des travailleurs entre les différentes méthodes intégrant leur perception. Par exemple, la réponse que nous donne un travailleur sur l'échelle de Borg (Borg 1998) quant à sa perception de l'effort qu'il doit fournir avec ses membres supérieurs est-elle cohérente avec la réponse qu'il nous a donnée dans le questionnaire de la méthode QEC?

Finalement, étant donné la somme de méthodes publiées au cours des dernières années, notre étude devrait être répliquée et couvrir un éventail plus varié de niveaux de risque de TMS (et non uniquement des postes jugés préoccupants).

6.5 Conclusion

Cette thèse s'est intéressée à l'évaluation des facteurs de risque de TMS. Elle compare les résultats obtenus à l'aide de 11 méthodes d'observation différentes et étudie le lien entre la déclaration de la douleur et la perception des travailleurs quant à l'évaluation de leur poste de travail. La thèse présente une analyse comparative de six méthodes d'évaluation des facteurs de risque de TMS au dos dans une première étude et huit méthodes dédiés à l'évaluation des facteurs de risque de TMS aux membres supérieurs et pour plusieurs zones corporelles dans le cadre d'une deuxième étude. Les résultats révèlent d'importantes différences entre les méthodes quant à la détermination du niveau de risque. Certains postes de travail sont identifiés comme comportant un risque faible de développer une lésion alors que d'autres méthodes jugent les mêmes postes à risque élevé. La troisième étude permet de constater que l'évaluation d'un expert est probablement préférable lorsqu'il s'agit d'identifier les postes à risque puisque les résultats démontrent que l'opinion du travailleur est moins fiable : les travailleurs ayant déclaré de la douleur perçoivent plus négativement leur poste de travail.

En somme, chacune des variables évaluées par les méthodes ainsi que le type d'intervention devraient être pris en compte lors du choix de la méthode d'observation. Dans le cadre de travaux futurs, d'autres analyses devraient être réalisées afin de déterminer l'effet de la pondération des différentes variables prise en compte par une méthode dans la détermination du niveau de risque. Considérant les résultats de cette thèse, la recherche devrait se poursuivre pour développer un outil d'aide à la décision quant au choix d'une méthode d'évaluation des facteurs de risque de TMS.

Le projet de recherche sur lequel s'est appuyé cette thèse nous a permis d'enrichir significativement la littérature en ergonomie par le nombre de méthodes d'évaluation des facteurs de risque de TMS qu'il compare. Les résultats qui découlent de notre large collecte de données, dans des milieux industriels variés, représentent une valeur ajoutée certaine par rapport aux quelques études qui comparent les méthodes d'observation sur de plus petits échantillons et/ou des milieux uniques. Les résultats apportent non seulement une nouvelle information utile quant aux résultats que produisent les différentes méthodes, mais ils permettent aussi de confirmer certains résultats d'études précédentes menées sur des échantillons de plus petite taille.

De façon générale, la diffusion de ces connaissances devrait permettre aux praticiens de mieux juger à l'avance des résultats lorsqu'ils font le choix d'utiliser une méthode plutôt qu'une autre pour effectuer l'évaluation d'un poste de travail. Finalement, pour les organismes responsables de la prévention et les entreprises désireuses d'adopter une méthode dans le cadre d'un programme de prévention des TMS, ces travaux devraient permettre de prendre des décisions plus éclairées.

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ANNEXE A

PRÉSENTATION DU QUESTIONNAIRE UTILISÉ

DANS LE CADRE DE LA COLLECTE DE DONNÉES

PROFIL ET ÉVALUATION DU TRAVAILLEUR

Étude ergonomique

Questionnaire

Profil et évaluation des travailleurs

Numéro du questionnaire : _______

Toutes les informations contenues dans ce questionnaire seront maintenues strictement confidentielles.

École Polytechnique de Montréal

Chaire de recherche du Canada en ergonomie

Département de mathématique et génie industriel

C.P. 6079, Succursale Centre-ville

Montréal, Québec, H3C 3A7

Nom : ___________________________

Date : ___________________________

PROFIL DU TRAVAILLEUR

1. **Usine : ____**

2. **Cellule : ____**

3. **Poste de travail : ____**

4. **Quart de travail (Jour / Soir / Nuit) : ____________________________________**

5. **Date de naissance: ____**

6. **Poids corporel (en lbs) : ____**

7. **Taille (en pi) : ____**

8. **Date d'embauche dans l'entreprise : ____________________________________**

9. **Date de début du travail au poste actuel: ________________________________**

10. **Quels sont les trois postes de travail où vous avez travaillé dans les 12 derniers mois en plus du poste actuel et ce, en commençant par les plus récents :**

Poste de travail	Date de début – Date de fin (durée)

QUESTIONNAIRE QEC - ÉVALUATION DU TRAVAILLEUR

Cochez la réponse appropriée et indiquez des précisions si vous le jugez pertinent.

H. Effort **Précisions :**

La charge que vous manipulez est :

H1: ______ Légère

H2: ______ Moyennement lourde

H3: ______ Lourde

H4: ______ Très lourde

J. Durée

Combien d'heures en moyenne par jour consacrez-vous à ce travail ou à cette tâche ?

J1: ______ Moins de 2 heures

J2: ______ De 2 à 4 heures

J3: ______ Plus de 4 heures

K. Force

Vous devez, avec votre main, forcer :

K1: ______ Un peu

K2: ______ Moyennement

K3: ______ Beaucoup

L. Précicion visuelle

Le niveau de précision visuelle dont vous avez besoin est :

L1: Faible (pas besoin de voir les détails)

L2: Élevé (besoin de voir les détails)

M. Vibrations d'un véhicule

Conduisez-vous un véhicule au travail ? Si oui, pendant combre d'heures par jour ?

M1: Jamais ou moins d'une heure

M2: Oui, de heure à 4 heures

M3: Oui, plus de 4 heures

N. Vibrations d'un outil manuel

Utilisez-vous des outils manuels qui vibrent ?

Si oui, pendant combien d'heures par jour ?

N1: Jamais ou moins d'une heure

N2: Oui, de heure à 4 heures

N3: Oui, plus de 4 heures

P. Rythme

Avez-vous de la difficulté à tenir le rythme de production ?

P1: Jamais

P2: Parfois

P3: Souvent

Q. Stress

En général, comment trouvez-vous votre travail ?

Q1:		Pas stressant	CSST :			
Q2:	______	Peu stressant	Q1:		Pas/peu stressant	
Q3:	______	Assez stressant	Q2:	______	Assez stressant	
Q4:	______	Très stressant	Q3:	______	Très stressant	

QUESTIONNAIRE FIOH À L'INTENTION DES TRAVAILLEURS

Donnez, *de façon générale*, l'évaluation de chacun des aspects suivants en leur attribuant l'indicateur qui correspond le plus à la situation de travail que vous vivez : **Tout à fait vrai (++), Plutôt vrai (+), Plutôt faux (-), Tout à fait faux (--)**. (Bon (++), moyen (+), mauvais (-), très mauvais (--)).

1. Le poste de travail

- Votre posture de travail est convenable pour l'exécution de la tâche : espace pour les jambes, hauteur de travail, poste de travail ajustable à votre taille ;

- L'aménagement du poste de travail n'empêche pas la réalisation de certains mouvements nécessaires à la tâche;

- Les équipements que vous utilisez pendant votre travail répondent bien aux besoins de la tâche : outils manuels, équipements d'aide à la manutention, équipement de protection individuel, tout autre équipement ou installation requis lors de l'accomplissement de la tâche ;

Commentaires :

____

____

____

++	+	-	--

2. La charge physique globale

- Le rythme de production (machinerie, cellule de travail précédente et suivante) impose peu le rythme de travail de votre poste et vous permet de choisir celui qui vous convient ;
- Les pauses vous permettent de vous reposer : vous n’êtes plus fatigué.

Commentaires :

____

____

____

++	+	-	--

3. Levées de charges

- Si vous levez une charge :
  i. le poids de la charge vous semble sécuritaire ;
  ii. la position pour saisir et transporter la charge est confortable ;

Commentaires :

____

____

____

++	+	-	--

4. Posture de travail et mouvement

- En considérant votre pire posture de travail et le mouvement le plus difficile que vous devez réaliser, vous constatez que :
  - i. votre cou et vos épaules sont en position naturelle et votre travail n'affecte pas leur position ;
  - ii. vos bras sont peu sollicités pendant votre travail ;
  - iii. votre dos est en position naturelle et votre travail n'affecte pas sa position ;
  - iv. vous pouvez bouger vos jambes librement pendant l'exécution de votre tâche ;

Commentaires :

____

____

____

++	+	-	--

5. Le risque d'accident

- Lors de l'exécution de votre tâche, les risques d'accidents sont faibles car vous ne faites pas d'effort soudain, il n'y a pas de risque associé au feu, à l'air comprimé ou au courant électrique, il n'y a pas d'arrête tranchante et il n'y a aucun risque de chute ou d'éclaboussure...

- S'il est possible qu'un accident se produise à votre poste de travail, il sera de faible gravité (une journée d'absence maximum) ;

Commentaires :

____

____

____

++	+	-	--

6. Contenu de la tâche

- Non seulement vous effectuez l'activité de base de votre tâche, mais vous pouvez aussi :
    i. planifier et préparer la tâche ;
    ii. inspecter et corriger votre travail ;
    iii. effectuer la maintenance et la gestion des appareils nécessaires pour faire votre travail ;

Commentaires :

____

____

____

++	+	-	--

7. Les contraintes de la tâche

- Il vous est possible d'organiser votre travail vous-même et de choisir librement quand et comment la tâche doit être effectuée;

- Votre tâche n'est pas contrainte par une machine, un procédé ou un travail de groupe ;

Commentaires :

____

____

____

++	+	-	--

8. Communication et contact personnel

- Vous pouvez communiquer facilement et rapidement avec votre supérieur et vos collègues de travail ;

Commentaires :

____

____

____

++	+	-	--

9. La prise de décision

- L'information pour vous guider dans votre tâche est claire, non ambiguë et en quantité suffisante;

- Cette information mène toujours à de bonnes décisions et n'entraîne jamais d'accident ou d'arrêt de production ;

Commentaires :

____

____

____

++	+	-	--

10. La répétitivité

- Les tâches que vous devez effectuer sont variées et non répétitives ;

Commentaires :

____

____

____

++	+	-	--

11. L'attention

- Votre tâche nécessite un niveau d'attention superficiel et des observations de courte durée ;

Commentaires :

____

____

____

++	+	-	--

12. Eclairage

- L'éclairage de votre poste de travail vous permet de bien distinguer les formes, les couleurs et les contrastes de sorte que vous n'êtes pas éblouis lors de l'exécution de votre tâche ;

Commentaires :

____

____

____

++	+	-	--

13. Environnement thermique

- Lors de l'exécution de votre travail, vous n'avez ni trop froid, ni trop chaud et ce à chaque partie de votre corps ;

Commentaires :

____

____

____

++	+	-	--

14. Le bruit

- Le niveau de bruit ambiant vous permet de communiquer facilement avec vos collègues et de vous concentrer sur votre travail ;

Commentaires :

____

____

____

++	+	-	--

QUESTIONS COMPLÉMENTAIRES À L'ANALYSE DU POSTE DE TRAVAIL (OCRA)

- Indiquez les actions qui demandent l'usage de la force dans ***les bras, les épaules ou les mains*** dans un cycle de travail normal.
- Évaluez chaque action précédente selon l'échelle de BORG (Échelle ci-dessous)
- Pour chaque action qui demande de la force, indiquez quelles en sont les raisons. (Ex. : mauvaise posture, poids, mauvaise prise, mécanisme mal adapté, …)

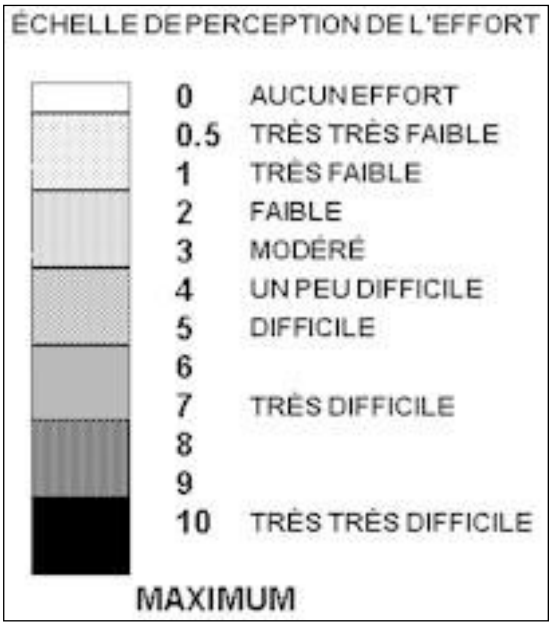


Figure 1. Échelle de BORG

Actions pour le poste « »	**Perception de l'effort**		**Cause de la présence de l'effort musculaire (si effort > 3)**
	Côté Gauche	**Côté Droit**	
Autre :			

QUESTIONS COMPLÉMENTAIRES À L'ANALYSE DU POSTE DE TRAVAIL (HAL)

- Indiquez les actions qui demandent l'usage de la force dans ***<u>les mains et les poignets</u>*** dans un cycle de travail normal.
- Évaluez chaque action précédente selon l'échelle de BORG (Échelle ci-dessous)
- Pour chaque action qui demande de la force, indiquez quelles en sont les raisons. (Ex. : mauvaise posture, poids, mauvaise prise, mécanisme mal adapté, …)

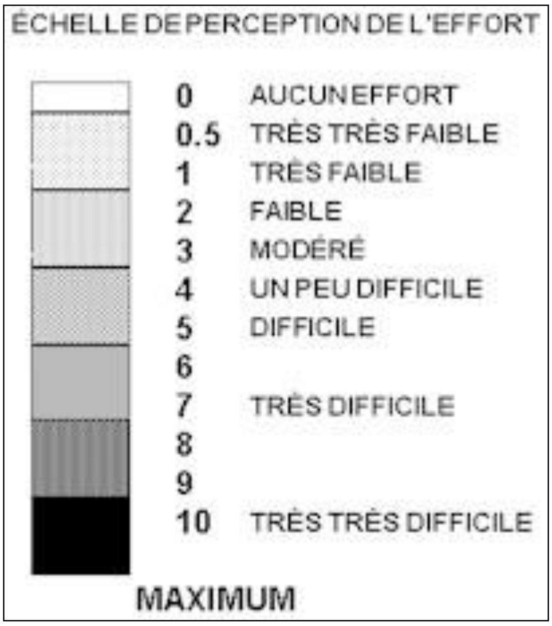


Figure 1. Échelle de BORG

Actions pour le poste « »	**Perception de l'effort**		**Cause de la présence de l'effort musculaire (si effort > 3)**
	Côté Gauche	**Côté Droit**	

Perceptions du travailleur

Quelle est votre perception quant à la qualité « ergonomique » de votre poste de travail ?

Pas du tout ergonomique

Tout à fait ergonomique

Commentaires :____

____

Quelle est votre perception quant à la nécessité des changements à apporter au poste de travail ?

Pas nécessaire du tout **Tout à fait nécessaire**

Commentaires :____

____

À la suite d’une intervention au poste de travail :

Comment évaluez-vous votre satisfaction concernant les transformations réalisées au poste de travail ?

Pas du tout satisfait **Tout à fait satisfait**

Commentaires :____

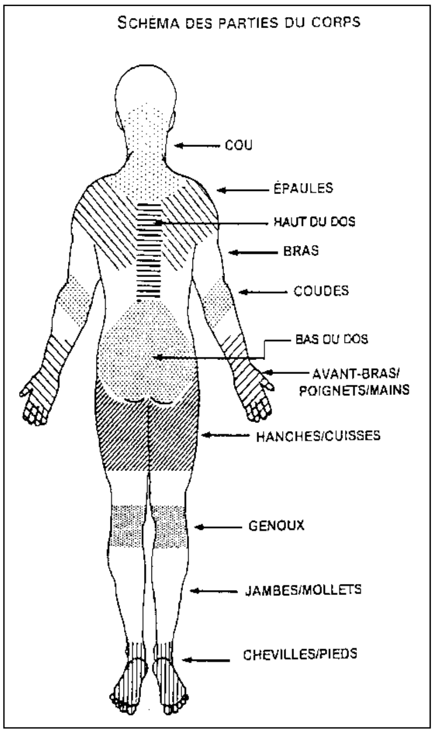
____

Douleurs ressenties au cours des 12 derniers mois

1. Au cours des 12 derniers mois, avez-vous ressenti des douleurs importantes à l'une ou l'autre des parties du corps suivantes qui vous ont dérangé (e) dans vos activités?

Consultez le schéma au bas de la page

	Jamais	De temps en temps	Assez souvent	Tout le temps
Cou	1	2	3	4
Épaules	1	2	3	4
Bras	1	2	3	4
Coudes	1	2	3	4
Avant-bras, poignets ou mains	1	2	3	4
Haut du dos	1	2	3	4
Bas du dos	1	2	3	4
Hanches ou cuisses	1	2	3	4
Genoux	1	2	3	4
Jambes, mollets	1	2	3	4
Chevilles ou pieds	1	2	3	4



2. Consultez le schéma et identifiez la partie du corps où vous avez ressenti la douleur qui vous a le plus dérangé (e) dans l'ensemble de vos activités au cours des 12 derniers mois?

- ☐ 1. Cou
- ☐ 2. Épaules
- ☐ 3. Bras
- ☐ 4. Coudes
- ☐ 5. Avant-bras, poignets ou mains
- ☐ 6. Haut du dos
- ☐ 7. Bas du dos
- ☐ 8. Hanches ou cuisses
- ☐ 9. Genoux
- ☐ 10. Jambes, mollets
- ☐ 11. Chevilles ou pieds

4 Croyez-vous que cette douleur soit reliée à votre travail?

- ☐ 1. Oui, reliée entièrement au travail
- ☐ 2. Oui, reliée en partie au travail
- ☐ 3. Non reliée au travail
- ☐ 4. Je ne sais pas si elle est reliée à mon travail

Douleurs ressenties au cours des 7 derniers jours

1. Indiquez pour chacune des parties du corps où vous avez ressenti de la douleur au cours des 7 derniers jours, si vous croyez que cette douleur était reliée ou non à votre travail.

Pour les parties du corps où vous n'avez ressenti aucune douleur, encerclez le « 1 ».

	Aucune douleur au cours des 7 derniers jours	Oui, reliée entièrement au travail	Oui, reliée en partie au travail	Non reliée au travail	Je ne sais pas si reliée au travail
	1	2	3	4	8
Épaules	1	2	3	4	8
Bras	1	2	3	4	8
Coudes	1	2	3	4	8
Avant-bas, poignets ou mains	1	2	3	4	8
Haut du dos	1	2	3	4	8
Bas du dos	1	2	3	4	8
Hanches ou cuisses	1	2	3	4	8
Genoux	1	2	3	4	8
Jambes, mollets	1	2	3	4	8
Chevilles ou pieds	1	2	3	4	8

2. a) Indiquez la partie du corps (région, site) pour laquelle vous avez ressentie la douleur la plus dérangeante au cours de 7 derniers jours dans votre travail :

____

b) Est-ce que la douleur la plus dérangeante dans votre travail que vous avez ressentie au cours des 7 derniers jours est :

☐ 1. Présente de façon continuelle

☐ 2. Présente après une période de travail continu de plus de 2 heures mais une fois apparue elle persiste pour le reste de la journée

☐ 3. Présente après une période de travail continu de plus de 2 heures mais diminue après une période de repos

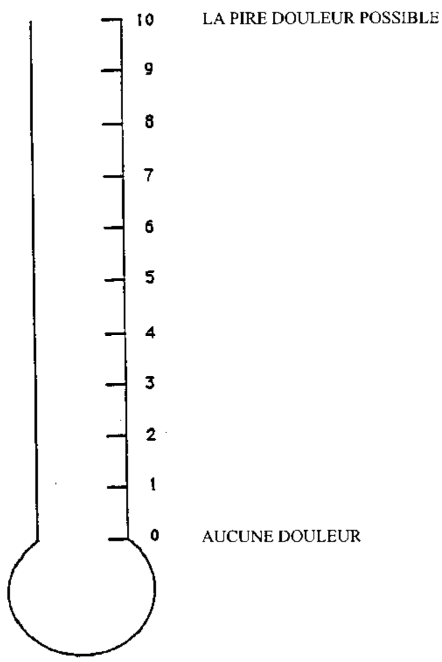
☐ 4. Présente surtout en fin de journée

☐ 5. Non applicable

3. Sur la figure du thermomètre où, le 0 indique aucune douleur, le 10 la pire douleur possible, indiquez moi pour <u>la région</u> (ou le site) où la douleur a été la plus dérangeante au cours des 7 derniers jours :

Région (ou site) DE LA DOULEUR : ______________

THERMOMÈTRE DE LA DOULEUR



☐ 1. La plus faible douleur que vous avez ressentie à cette région?

____

☐ 2. La plus forte douleur que vous avez ressentie à cette région?

____

☐ 3. La douleur moyenne que vous avez ressentie à cette région?

____

☐ 4. Non applicable

Force de préhension

Essai 1	Essai 2	Essai 3

Force exercée (mesurée avec la balance)

Élément	Essai 1	Essai 2	Essai 3